DOCUMENT RESUME

ED 245 924 SE 044 658

AUTHOR	Irby, Bobby N., Comp.; And Others
TITLE	Diversity of Marine Animals. Man and the Gulf of Mexico Series.
INSTITUTION	Mississippi-Alabama Sea Grant Consortium, Ocean Springs, Miss.
SPONS AGENCY	National Oceanic and Atmospheric Administration (DOC), Rockville, Md. National Sea Grant Program.
REPORT NO	ISBN-0-87805-203-8; MASGP-82-007(4)
PUB DATE	84
GRANT	NA81AA-D-00050
NOTE	127p.; For other volumes in this series, see ED 239 869-970 and SE 044 659.
AVAILABLE FROM	University Press of Mississippi, 3825 Ridgewood Rd., Jackson, MS 39211.
PUB TYPE	Guides - Classroom Use - Materials (For Learner) (051) -- Guides - Classroom Use - Materials (For Learner) (051)
EDRS PRICE	MF01 Plus Postage. PC Not Available from EDRS.
DESCRIPTORS	*Animal Behavior; *Animals; Classification; High Schools; *Marine Biology; *Marine Education; *Science Activities; Science Education; *Secondary School Science; Vocabulary Skills; Wildlife
IDENTIFIERS	Alabama; Mississippi

ABSTRACT

"Man and the Gulf of Mexico" (MGM) is a marine science curriculum series developed to meet the needs of 10th through 12th grade students in Mississippi and Alabama schools. This MGM unit on the diversity of marine animals is divided into 16 sections. These sections focus on: marine protozoans; sponges; coelenterates; ctenophores; polychaetes; mollusks; echinoderms; barnacles; the blue and hermit crabs; shrimp; horseshoe crabs; sea squirts; sharks and stingrays; common seashore birds; marine turtles; and marine mammals. Each section includes a statement of concept(s) to be learned, objectives, text material, and a vocabulary list. In addition, one or more activities (including vocabulary activities) are provided in the sections on marine protozoans, sponges, coelenterates, polychaetes, mollusks, barnacles, blue and hermit crabs, common seashore birds, and marine mammals. Objectives, list of materials needed, and procedures are provided for these activities, which investigate such areas as: salinity and small animals; sponge structure; general and feeding behavior of "Hydra"; reaction of "Nereis" to a changing environment; anatomy and feeding behavior of barnacles; marine organisms and osmotic tolerance; and the world of whales. (JN)

Diversity of Marine Animals

Man and the Gulf of Mexico Series

Compiled and edited by
Bobby N. Irby
Malcolm K. McEwen
Shelia A. Brown
Elizabeth M. Meek

Published for the
MISSISSIPPI-ALABAMA SEA GRANT CONSORTIUM
by the
UNIVERSITY PRESS OF MISSISSIPPI
Jackson

Other titles in the
Man and the Gulf of Mexico Series

Marine and Estuarine Ecology
Marine Habitats
Diversity of Marine Plants

Library of Congress Cataloging in Publication Data

Main entry under title:

Diversity of marine animals.

(Man and the Gulf of Mexico series)
Bibliography: p.
Includes index.
Summary: A high school textbook introducing the physical characteristics, behavior, and natural environment of a variety of marine animals.
1. Marine fauna—Mexico, Gulf of. 2. Marine ecology—Mexico, Gulf of. [1. Marine animals. 2. Marine ecology. 3. Ecology.] I. Irby, Bobby N. II. Mississippi-Alabama Sea Grant Consortium. III. Series.

QL122.2.D58 1984 591.92 83-19721
ISBN 0-87805-203-8

This publication is a part of an educational series sponsored by NOAA Office of Sea Grant, U.S. Department of Commerce, under Grant Number: NA81AA-D-00050, the Mississippi-Alabama Sea Grant Consortium, the University of Southern Mississippi and the University of South Alabama. The U.S. Government is authorized to produce and distribute reprints for governmental purposes notwithstanding any copyright notation that may appear hereon.

PROJECT STAFF

Dr. Bobby N. Irby
Principal Investigator
Chairman, Department of Science Education
University of Southern Mississippi
Hattiesburg, MS 39406

Dr. Malcolm K. McEwen
Evaluator and Curriculum Consultant
Department of Science Education
University of Southern Mississippi
Hattiesburg, MS 39406

Dr. Shelia A. Brown
Associate Investigator
Curriculum Consultant
University of Southern Mississippi
Hattiesburg, MS 39406

Dr. Elizabeth M. Meek
Associate Investigator
Curriculum Consultant
University of South Alabama
Mobile, AL 36688

CONTRIBUTORS

Dr. Shelia A. Brown
Mr. Gerald C. Corcoran
Dr. Bobby N. Irby
Dr. Malcolm K. McEwen
Dr. Elizabeth M. Meek
Dr. Marlene M. Milkent
Dr. Lloyd E. Story

TYPISTS

Barbara B. O'Brien
Kay Everett
Lois P. Irby

CLERKS

Susan Stewart
Maureen Corcoran
Leona S. Woullard
Mary Woodard

ILLUSTRATORS

Teri Kinslow
Richard Ford
Mollie Rollins

TEACHER CONSULTANTS

Joe Ash
Beatrice Blount
Taska Brantley
Margaret Caldwell
Ann Carothers
Hargie Crenshaw
Robert Crittenden
Mervin Denton
Mary Ann Erdman
Sam Etheridge
Angela Faulkenberry
Iva Nell Fortenberry
Jean Graben

Cathy Griffon
Jiles Grice
Fred Haberle
Wattine Hannah
Ray Hargrove
Louise Hayles
Tommy Herren
Bill Herbert
Diana Jones
Dr. Ralph Jones
Rebecca Jones
Kathleen Kilgen
Harry Kittle

William Lay
Gerald Lexa
John Lovett
Dr. Johnny Mattox
William McClain
Guy McClure
Faith McCullen
Bessie Moffatt
Marie Patrick
Lelia Patterson
Leonard Ring, Jr.
Harmon Ross
Jessica Scott

Sarah Sims
Carol Smith
Linda Standridge
Dorothy Steinwinder
Silvia Wallace
Madeene Watts
Raymond Werthner
Lou White
Dan Whitson
Martha Wilson
Charles Wolffarth
Janice Woodall

TEST-CENTER TEACHERS, 1980-81

Robert Crittenden
Auburn High School
Auburn, AL

Mervin Denton
McComb High School
McComb, MS

Mary Ann Erdman
Baker High School
Mobile, AL

Iva Nell Fortenberry
Monticello High School
Monticello, MS

Wattine Hannah
Gulfport High School
Gulfport, MS

Diana Jones
Woodland High School
Woodland, AL

Rebecca Jones
Fairhope High School
Fairhope, AL

William Lay
Hamilton High School
Hamilton, MS

Bessie Moffatt
Pascagoula High School
Pascagoula, MS

Marie Patrick
Foley High School
Foley, AL

Silvia Wallace
Strider Academy
Webb, MS

Raymond Werthner
St. Martin High School
Biloxi, MS

TEST CENTER TEACHERS, 1981-82

Sarah Ainsworth
Hernando High School
Hernando, MS

Timothy Benjamin
East Union Attndnce. Cntr
Blue Springs, MS

Janice [illegible]d
Carver Junior High School
Montgomery, AL

Peggy Croutch
Gulfport High School
Gulfport, MS

Richard Davis
Hamilton High School
Hamilton, AL

Wattine Hannah
Gulfport High School
Gulfport, MS

Louise Hayles
Moss Point High School
Moss Point, MS

Sharon Johnson
Petal High School
Petal, MS

William Lay
Hamilton High School
Hamilton, MS

Bill Lee, Jr.
McGill-Toolen High School
Mobile, AL

Jane Lusk
Starkville High School
Starkville, MS

Lenora McWhorter
Cedar Bluff High School
Cedar Bluff, AL

Bessie Moffatt
Pascagoula High School
Pascagoula, MS

Jane Nall
Escambia Cnty High School
Atmore, AL

Marie Patrick
Foley High School
Foley, AL

Billy Pierce
Decatur High School
Decatur, MS

Sarah Sims
Prattville High School
Prattville, AL

Elsie Spencer
Opp High School
Opp, AL

Mary Ulrich
Provine High School
Jackson, MS

Brenda Vaughn
Huntsville [illegible] School
Huntsville, AL

Silvia Wall[illegible]
Strider Academy
Webb, MS

STATE DEPARTMENT OF EDUCATION CONSULTANTS

Donna Bentley
Science Specialist
Alabama State Department of Education

Michael Carothers
Consultant, Science and Environmental Education
Mississippi State Department of Education

Edward Ford
Science Specialist Aerospace
Alabama State Department of Education

CONTENTS

Preface

> *"If the oceans of earth should die . . . it would be the final as well as the greatest catastrophe in the troublous story of man and the other animals and plants with whom man shares this planet."*
>
> —JACQUES COUSTEAU

Cousteau's warning appropriately summarizes the need to include marine education in our curriculum today. The history of mankind is closely linked to the ocean. Man has always been awed by the vast expanse of the sea. It is ironic indeed that such a valuable resource has been neglected so long in education.

"Man and the Gulf of Mexico (MGM)" is a marine science curriculum developed for grades 10–12 with funds from the Mississippi-Alabama Sea Grant Consortium. The MGM materials were specifically designed to meet the need for marine science in all secondary schools of Mississippi and Alabama.

The MGM project was a two-state effort, invol[illegible] University of Southern Mississippi, the University of South Alabama, and the [illegible] Coast Research Laboratory in cooperation with the Alabama and Mississippi State Departments of Education. Similarities among the coastal problems of the two states not only made this an appropriate arrangement, but also heightened the potential for success of the project. Additionally, the educational needs for increased dissemination of marine studies in the public schools of the sister states are equally urgent. Perhaps the most significant feature in the development of the MGM materials was the cooperation between university science educators, innovative secondary school science teachers and other resource personnel. These cooperative relationships were established at the outset of the project and continued throughout the duration of the curriculum development effort. The design, development, field testing, revision, and a second field test evaluation spanned four years of intensive and dedicated work.

During the initial phase of the MGM project, selected high school science teachers responded to a questionnaire designed to provide information concerning each teacher's impression of the importance of certain marine topics, each teacher's self-assessment of his/her knowledge of the same marine topics, and each teacher's preference in terms of curriculum format. Results of the survey were used to provide direction for the selection of topics and for the development of activities to be included in the materials. The completed materials include four units: *Marine and Estuarine Ecology, Marine Habitats, Diversity of Marine Animals,* and *Diversity of Marine Plants.* Field testing of the materials was conducted in eleven schools by biology teachers during 1980–81. Included were two inland and two coastal districts in Alabama and four inland and three coastal districts in Mississippi. Based on those classroom evaluations, the materials were thoroughly revised during the summer of 1981. The revised materials were then used in 35 schools throughout Alabama and Mississippi during the 1981–82 academic year.

The field-testing of the MGM materials in the classroom has demonstrated that the marine science materials are equally appropriate for both inland and coastal schools. Many teachers have successfully incorporated selected MGM materials into their existing courses of study in biology, while others have used the complete curriculum as a separate course in marine science. In either case, teachers have found the MGM Marine Science Curriculum enjoyable to teach and very informative.

Information and activities indexed and accumulated on microfiche through the Marine Education Materials system (MEMS) have been invaluable during preparation of the MGM units. Some of the activities and concepts included as a part of MGM were modified from resources in the MEMS collection. Appropriate credit is given to the original authors in the reference section of each MGM unit. We are particularly indebted to the following marine education curriculum projects for their contributions: "Man and the Seacoast", a project sponsored by the University of North Carolina Sea Grant College Program which resulted in the publication of the *North Carolina Marine Education Manual* series; "Project COAST" (Coastal/Oceanic Awareness Studies), funded by the Delaware Sea Grant College Program; and the *Hawaii Marine Sciences Study Program* developed by the Curriculum Research and Development Group at the University of Hawaii.

We wish to acknowledge the cooperation that we have received from other marine education projects, the Alabama and Mississippi State Departments of Education, The University of Mississippi Law School, the National Marine Education Association, and many individuals who offered suggestions that were incorporated into the MGM materials. Our gratitude is also extended to Dr. J. Richard Moore for permission to include his plant key in the teacher supplement for *Diversity of Marine Plants*. We are indebted to the Department of Science Education at the University of Southern Mississippi for serving as a base of operation, allowing use of its equipment, and providing financial support. We especially would like to thank all of the dedicated Mississippi and Alabama teachers who worked so diligently on MGM materials. We hope that high school students and their teachers will continue to find that these efforts have been of value.

Bobby N. Irby
Malcolm K. McEwen
Shelia A. Brown
Elizabeth M. Meek

DIVERSITY of MARINE ANIMALS

Objectives of *Diversity of Marine Animals:*

1. To help students realize the diversity of organisms present in the marine environment.
2. To present general information relative to the various animals that live in the marine environment.
3. To compare and contrast adaptations made by groups of marine animals in order to survive in their particular habitats.
4. To provide students with various types of experiences that will help them become proficient in identifying some of the common marine animals.

CONCEPT A

Even though protozoans are very small organisms, they possess a variety of structural characteristics which aid in the identification of specific protozoans.

Objectives

Upon completion of this concept, the student should be able:

a. To identify a radiolarian, foraminiferan, and a tintinnid when presented with pictures of various protozoans.
b. To compare the methods of locomotion used by foraminiferans, radiolarians, and tintinnids.
c. To list several reasons for the economic importance of foraminiferans.
d. To name and discuss the similarities and differences between radiolarian skeletal types.
e. To sketch a generalized radiolarian. foraminiferan, and tintinnid.
f. To discuss the importance of radiolarians and foraminiferans to the ecosystem.

MARINE PROTOZOANS (PHYLUM PROTOZOA)

By far the largest number of marine invertebrates are neither edible delicacies nor large conspicuous creatures of the shore; nor floating animals seen from a boat. They are the tiny single-celled creatures that float and drift with the **plankton** in the upper level of the ocean. These single-celled animals comprise the first phylum of animals called the Phylum Protozoa ("proto" means first and "zoon" means animal). Even though the protozoans are extremely small organisms, they do play a very important role in the food chains of the ocean. These organisms provide the basic food material upon which many higher animals ultimately depend for their existence.

When we study typical protozoans, we usually read about amoeba, paramecium, vorticella, or stylonychia. In this concept, however, we will examine some other very anicent forms of protozoans. Some of these protozoans are relatives of the very familiar amoeba. We will call these protozoans radiolarians and foraminiferans (forams). Others are relatives of the paramecium and are known collectively as tintinnids. These organisms, which are still present in the marine habitat, were very important in our past as indicated by the huge deposits of fossilized shells found on some land areas that have been elevated above sea level.

Foraminiferans

One group of **benthic** protozoans is the foraminiferans. There are a few **pelagic** forams, of which *Globigerina* may be the most common (Figure 1). Shells secreted by the forams are made up of calcium carbonate or **tectin.** The shells exhibit a great diversity in size and shape (Figure 2). These shells consist of perforated chambers which house the protoplasm of the living animal. Some species secrete only one chamber while others may secrete many chambers. Those that secrete one chamber are known as **unilocular foraminiferans** while those with several chambers are called **multilocular foraminiferans.** The multilocular foraminiferan chambers may lie in a straight line, overlap, or they may form a spiral. Most of the foram shells now being deposited in the oceans are those of *Globigerina,* a planktonic foram (Figure 1). These animals are constantly dying and their skeletons sinking in a slow but steady rain to the ocean floor. Here they form a gray mud called "*Globigerina* ooze", a specialized type of **foraminiferal ooze.** Thirty-five percent of ocean bottoms are covered with thick deposits of foraminiferal ooze. The ooze is composed of shells of dead forams usually in association with the calcium carbonate remains of a group of algae called coccolithophores.

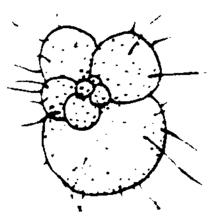


Figure 1. *Globigerina.*

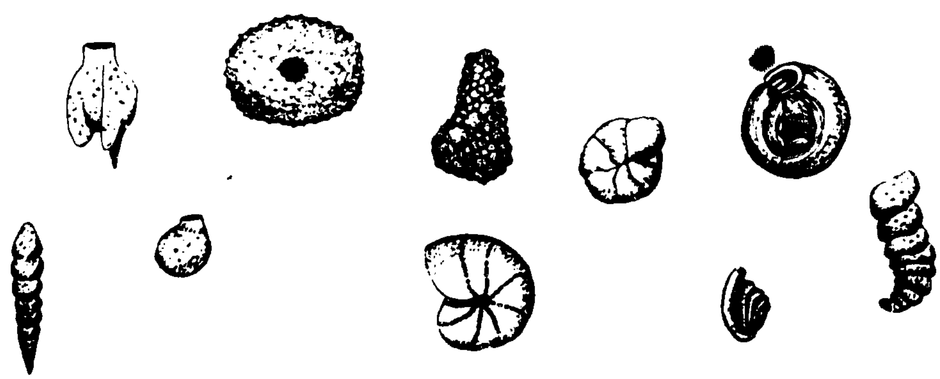


Figure 2. Diversity of Foram Shells.

Since forams are relatives of the amoeba, they move about by **pseudopodia.** The pseudopodia extend through small perforations in the shell. These pseudopodia are not as large as those of the amoeba, but they are still used in collecting protozoans, algae, and bacteria for food. Each pseudopod is very sticky, and the prey adheres to its surface. A granular film of mucous-like material on the surface of the pseudopod quickly coats the surface of the prey organism. This coating helps to paralyze the prey and may even start digestion as the food is taken into the interior of the animal.

Forams have also been found to be economically important. By taking **core samples** and analyzing the different species of forams present, the age of the core sample can be determined. By comparing samples taken in various geographical locations, past climatic changes on the major continents can be determined with some degree of certainty. The dating of the core samples also aids in the search for oil. In addition, some foram shells serve as nuclei of manganese nodules in the ocean floor. These are thought to be of value to speculators of deep sea mining. It is possible that great mineral wealth can be detected by locating these kinds of nodules.

Radiolarians

The radiolarians are very large protozoa, sometimes reaching diameters of several centimeters when in colonies. Individual radiolarians may reach several millimeters in diameter. The radiolarians are mostly pelagic.

The body of the radiolarian is usually spherical with an outer portion made of cytoplasm and an inner nucleated portion. The outer portion is called the **calymma,** whereas, the inner portion is referred to as the **central capsule** (Figure 3). A membrane surrounds the central capsule. Perforations (holes) in this membrane allow the cytoplasm to be continuous between the two portions of the cell. **Symbiotic** algae called **zooxanthellae** are often found in the calymma. By carrying on photosynthesis, these algae serve as a food source for the radiolarian. **Vacuoles** which have been noted in the calymma are thought to function in buoying up the animal. This represents an additional **adaptation** to allow the organism to remain in the upper layers of water.

These organisms contain specialized forms of pseudopodia. They are needle-like in shape and extend through the cytoplasm to the outside (Figure 3). Radiolarians' claim to fame are their skeletons. It has been said that radiolarian skeletons are among the most beautiful structures in the living world. There are two major types of radiolarian skeletons, **radiating** and **lattice** (Figures 3 and 4). Each of these types of skeletons is predominantly composed of silicon. The radiating type possesses long needles which originate from the central capsule and pass through the organism to the outside surface. **Contractile fibrils** are located on areas of the body where the needles penetrate the cell surface. The fibrils allow the spines and calymma to contract along with the contractile vacuoles. This mechanism, expansion and contraction, is adequate to control the depth of the organisms in the water column.

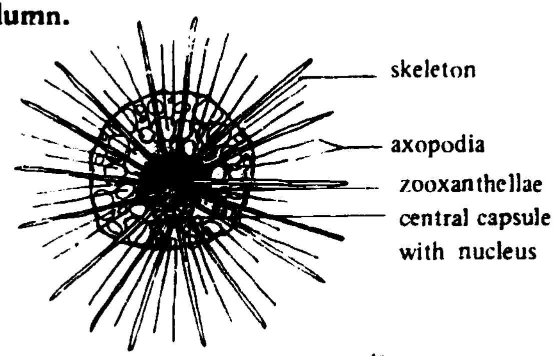


Figure 3. Radiating Skeleton of a Radiolarian.

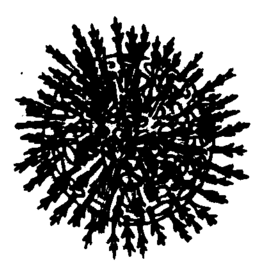


Figure 4. Lattice Skeleton of a Radiolarian.

The lattice skeleton is just a lattice sphere. These delicate, lace-like skeletons can be sculptured or armored in all imaginable ways. They may even have long sculptured tentacle-like structures adhering to one end of the sphere (Figure 5).

The radiolarians feed in a manner similar to that of the foraminiferans. Prey organisms become attached to the sticky pseudopodia, are covered with a granular slime, and are finally drawn into the body. Digestion usually occurs in the calymma portion of the radiolarian cell. Biologists think that if bright sunlight is present heterotrophic feeding may not be necessary. It is important to note that the pseudopodia of radiolarians are used in feeding, but not in locomotion. Rather, locomotion is accomplished by expansion and contraction of the calymma. The varying calymmal vacuoles enable the organisms to move up or down the water column.

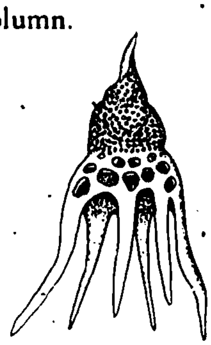


Figure 5. Sculptured Lattice Skeleton of a Radiolarian.

Tintinnids

One of the best known groups of common marine protozoans that have cilia is the tintinnids (Figure 6). These are the armored protozoans which usually show up in marine planktonic samples. The organism's armor is called a lorica (Figure 6). The animal is attached to the bottom of the lorica and protrudes from the mouth or top opening. The lorica is composed of a clear organic material which may have sand grains or other detritus cemented into it. It is filled with a low density fluid which allows it to float in the upper layers of water. Since the animals are ciliate protozoans, the fleshy portion of the cell is covered with cilia.

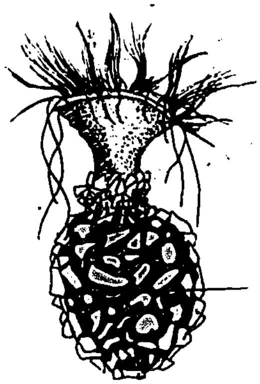


Figure 6. A Tintinnid.

The tintinnids feed on microscopic plants and bacteria by movement of membranes around the mouth of the lorica. They appear to fill just about the same ecological niche as the freshwater paramecia. It is very easy to recognize the tintinnid in a planktonic sample because of the granular vase-like structure, the most distinguishing structural characteristic.

VOCABULARY

Adaptation—the process by which a species becomes better suited to survive in an environment.

Armor—a hard, outer covering.

Benthic—bottom dwelling organisms.

Calymma—the outer portion of the radiolarian's cytoplasm.

Central capsule—the inner portion of the radiolarian's cytoplasm that is nucleated.

Cilia—tiny, hairlike projections; used for locomotion in some one-celled organisms.

Contractile fibrils—structures used by radiolarians to aid in controlling their depth in the water column.

Core sample—a vertical, cylindrical sample of the bottom sediments.

Detritus—very small particles of the decaying remains of dead plants and animals; an important source of food for many marine animals.

Foraminiferal ooze—an ocean bottom sediment consisting of 30% or more foram skeletons.

Heterotrophic feeding—the process of using food material produced by other organisms.

Lattice skeleton—a type of radiolarian skeleton which is delicate and lace-like.

Lorica—a "container" within which a tintinnid is housed. It is either secreted by the organism or composed of foreign material cemented together.

Multilocular foram—a foram that secretes several chambers.

Mucus—a slimy lubricating and cleansing secretion ("mucous" is an adjective; "mucus" is a noun).

Pelagic—inhabiting the open water of the ocean, rather than the bottom of the shore.

Plankton—small plants and animals floating in the upper layers of the water column.

Pseudopodia—a "false foot", formed by an extension of cytoplasm. It serves as a means of locomotion and a way of surrounding and thereby absorbing food.

Radiating skeleton—a type of radiolarian skeleton composed of silicon and possessing long needles which pass through the organism to the outside surface.

Symbiosis—the relationship in which two organisms live together in close association.

Tectin—an organic matrix with embedded grains of sand.

Unilocular foram—a foram that secretes a single chamber.

Vacuoles—small cavities that may contain secretions of the protoplasm or substances about to be excreted.

Water column—the area from the water surface to the bottom.

Zooxanthellae—symbiotic one-celled algae found in coral, sea anemones, mollusks, and other types of marine organisms.

CONCEPT REVIEW ACTIVITY

This activity is designed to help you organize some of the information that has been presented in this concept. Fill in the columns in the table using the material covered in this concept. Upon completion, this table will be an excellent study guide for you to use.

MARINE PROTOZOA	Related To	Benthic or Pelagic	Means of Movement	Skeleton Made of	Economic Importance	Form Ooze?	Autotrophic or Heterotropic	Shape
Foraminiferans								
Radiolarians								
Tintinnids								

Activity: Salinity and Small Animals

Objective

To determine if different salt concentrations affect the living organisms of a given aquatic (water) community.

Of the several **abiotic** environmental factors, **salinity** is of great importance. The salinity of natural waters varies, but it is almost a constant value in the open ocean. As organisms come closer to shore and toward the mouth of a freshwater stream there may be great fluctuations in the concentration of **salts** in the water. The tolerance to these salts also varies from organism to organism. Some organisms can live only in very salty waters, while others can only live in fresh water environments. There are still others that can move from one extreme to the other without causing physiological harm to the organism.

We find that sodium chloride is by far the most abundant salt in natural waters; therefore, we shall use it in our investigation. Professional **oceanographers** express the amount of salt in solution as parts of salt per thousand parts of water. In our activity, we shall express the amount of salt in solution as percentages.

Materials (per team of two students)

sodium chloride solution (1%, 3% and 5%), distilled water or tap water, microscope, microscope slides, microscope coverslips, clock, medicine dropper, paper towels, three cultures of small aquatic animals (paramecium, euglena, amoeba)

Procedure

With your medicine dropper, place a drop of water containing the organism you intend to study first on a microscope slide. Place a coverslip over the drop of water. If you are using a rather large organism, do not use the coverslip. For at least two minutes observe the normal behavior of the organism. Now, add one drop of the one percent salt solution to your sample. If you are using the coverslip draw the salt across using a paper towel as you have in other microscopic activities. As the salt moves across the slide, carefully observe the living organism. Record any changes in behavior that you observe. Also record the time when the reaction began. Continue to observe the organisms until no new reactions occur. Now, replace the salt water with tap water and observe the recovery of the organism. (The organism may not recover.) Record the length of time for recovery.

Repeat this investigation with the same organism using the 3% salt solution, and then the 5% salt solution. Complete the data table for each solution.

Now, repeat the entire investigation with the other two selected organisms. Record all data on the accompanying data sheet.

Data Sheet

	Salinity Used	Kind of Response	Average Time to Respond	Was there a Recovery	Average Time to Recover
Organism 1					
Organism 2					
Organism 3					

Extending Your Thoughts

1. Did each organism respond the same to the 1% salt solution? ______ Explain.
____
2. Did the change in concentration of salt seem to make any difference?______________
____Explain
____
3. What kind of habitat do you think that these organisms prefer?______________
Why?____
____
4. Did you kill any organisms? ____________ What were they? ______________
____
5. Which organism seemed to be the most tolerant to salt?______________
6. Which organism seemed to be the least tolerant to salt?______________
7. Which of these organisms might be found in the most diversified kinds of waters?
______________ Why would you think so?______________
____
8. In the marine environment would you expect to find any of these organisms?
______________ Why?______________
9. If you could find these in the marine environment, where do you think they might occur?______________

VOCABULARY

Abiotic factors—physical (non-living) aspects which interact with the organisms of an ecosystem.

Environment—the surroundings of an organism.

Habitat—the place where an organism lives.

Oceanographer—a scientist who deals with the physical geography of oceans, seas, and marine life.

Salinity—the total amount of dissolved salts present in a given amount of substance.

Salts—chemical compounds that are derived from acids by replacing the hydrogen wholly or partly with a metal or a nonmetal.

CONCEPT B

The sponges are the most primitive multicellular organisms.

Objectives

Upon completion of this concept, the student should be able:

a. To list the three classes of sponges and their predominent skeletal materials.
b. To describe the feeding and respiratory method employed by asconoid sponges.
c. To list four basic sponge cell types and the function of each.
d. To explain the function of spicules.
e. To describe a method of sponge reproduction that is important to the sponge industry.
f. To describe the regeneration of sponges from dissociated cells.
g. To discuss the importance of sponges to the ecosystem.
h. To discuss the economic importance of sponges.

THE SPONGES (PHYLUM PORIFERA)

When compared to other animals, sponges are very simply organized. Essentially, they are bags which pump water in through a great number of surface openings for feeding, gas exchange, and excretion. The water flows out of the organism through a large excurrent opening. All sponges are **sessile** organisms. Their most frequent **habitat** is the bottom of shallow coastal waters, but they are also found in deep water. A few have become adapted to a life in freshwater. Most of the common species of sponges are brightly colored. Green, yellow, orange, red, and purple sponges are frequently found.

Classification

There are three classes of sponges: **calcareous sponges, glass sponges,** and the Demospongia. Skeletons of the Demospongia are composed of **spicules** of silicon compounds, a protein called **spongin,** or both (Figure 1). The Demospongia include the commercial sponges.

Body Plan

While there are three basic types of sponge organization, we shall only discuss the simplest type, **asconoid** organization. Asconoid sponges are simple, saclike sponges which draw water in through small pores (holes) in the body wall called **ostia.** Those pores empty into a large central cavity, the spongocoel. The water then flows out a large opening at one end of the sponge called an **osculum** (Figure 2).

Movement of water through the sponge is important in bringing food to the organism. In addition, new water is essential to respiration and other vital activities of the sponge. This water is drawn into the sponge only at its surface. The constant renewal of the water allows the uptake of oxygen by sponge cells and the release of their carbon dioxide and other metabolic products. Cells throughout the sponge's body must have their surrounding water renewed at rates compatible with vital processes.

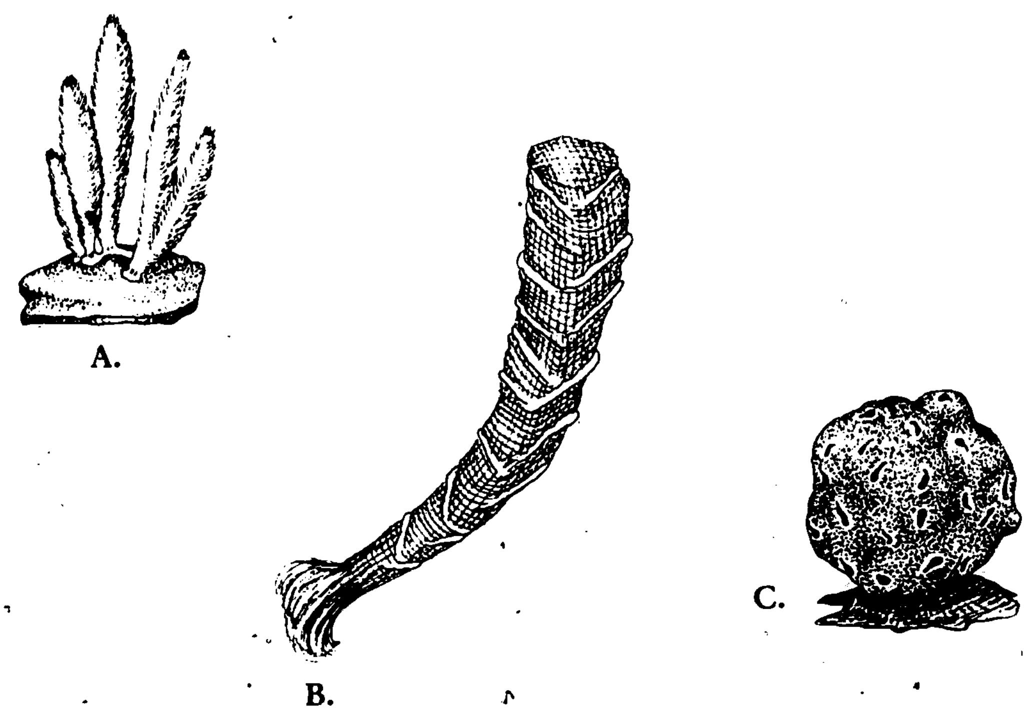


Figure 1. Classes of Sponges. A, Calcareous sponge. B, Glass sponge. C, Demospongia.

As the sponge increases in size, the volume increases faster than the surface area. A certain point is eventually reached where the amount of water drawn in through the surface cannot meet the needs of the cells throughout the body of the sponge. The success of solving the surface area-volume problem is reflected in the maximum size of sponges built on the three types of organization. The simple asconoid sponges never grow over about 10 cm high, while sponges with other types of organization reach greater maximum sizes.

Cell Types

An asconoid sponge is made up of four basic cell types called **pinacocytes, porocytes,** collar cells, and **amebocytes.** The pinacocytes cover the outside as an epidermis, called the pinacoderm, while the collar cells line some of the internal surfaces. Between these two cell layers is a jelly-like substance called **mesoglea.** The amebocytes crawl about in the mesoglea (Figure 2).

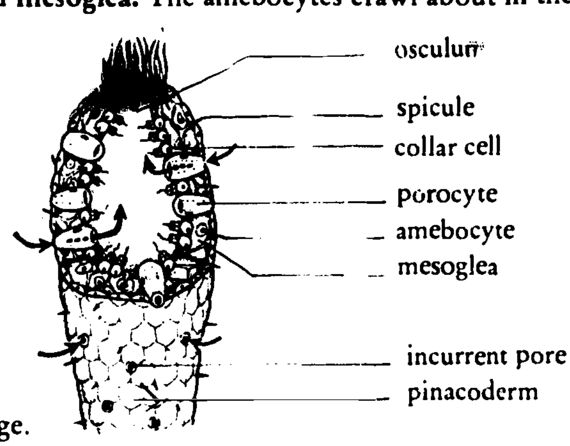


Figure 2. Internal Structure of a Sponge.

Porocytes are tubular cells unique to sponges. The incurrent pores, or ostia, pass through the center of the porocytes. The outer surfaces of the porocytes are found scattered among the cells of the epidermis. They extend through the mesoglea into the spongocoel, allowing water to pass into the **spongocoel.** The outer ends of the ostia can be closed to prevent the entrance of water.

The collar cells are the actual water-moving cells. They are more or less round cells with a clear collar extending into the spongocoel. Rising out of the collar is a whiplike **flagellum** which is constantly beating, moving the water toward the osculum. The exit of water from the osculum allows more water to flow into the spongocoel through the ostia. In this manner, a constant current of water is drawn through the sponge. The collar cells pick food particles out of the water and ingest them. The collar cells pick food particles out of the water and enzymes within the cells digest the collected food material.

The amebocytes are the workhorse cells of the sponge. They creep about the sponge like small amoebas. It is unclear whether there is one adaptable kind or several kinds, but amebocytes have a variety of functions. Amebocytes absorb digested food material from the collar cells and travel throughout the sponge distributing this substance to other cells. Some amebocytes develop slender **pseudopodia** and may group together in a mass containing pigments or food. Others form **sperm** and **ova.** Porocytes and collar cells have been seen to convert to amebocytes. Other amebocytes secrete limy or glass spicules or spongin fibers which form the skeleton of the sponge.

Skeletal Structures

The skeleton of the sponge is made of spicules. The spicules are small, complex crystalline structures laid down by amebocytes. They may be rods, stars, anchor-like objects, gridworks, needle shapes, or a host of other forms (Figure 3). They may be composed of silicon or calcium. Some of the spicules form major skeletal structures, while others are randomly scattered in the soft parts of the sponge. The form and composition of spicules are very important in the identification of sponges.

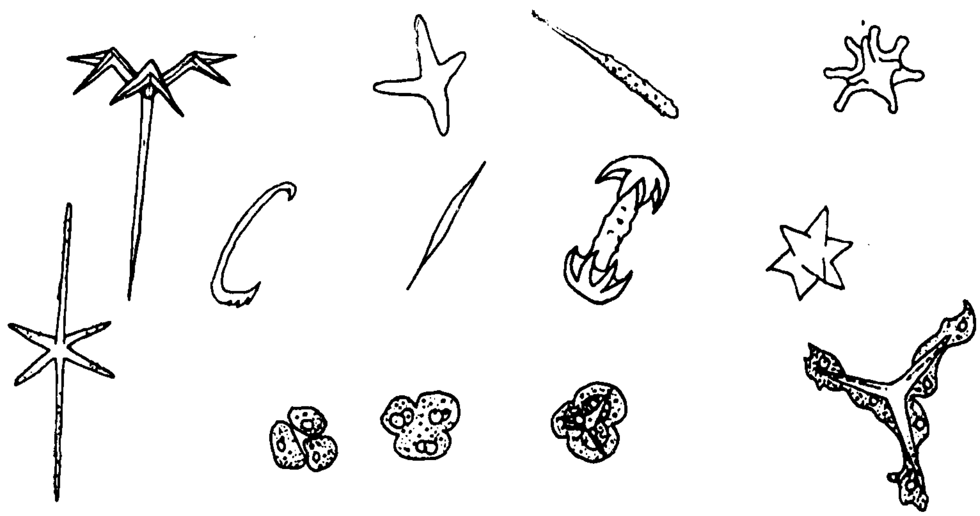


Figure 3. Diversity of Spicule Shapes.

Reproduction

Budding and **fragmentation** are asexual methods of reproduction used by sponges. Budding is the most common form. In this process, a bud appears on the side of the sponge. The bud differentiates into a young sponge. The young sponges may detach from the parent to take up an independent life or remain attached as a member of a colony of parents and offspring.

Fragmentation consists of the regeneration of a new sponge from bits and pieces of another sponge. The fragment may come from breakup due to unfavorable environmental conditions or as a normal part of the life history of the sponge. Fragmentation is quite important to man. A large sponge may be cut into many smaller pieces, weighted with a rock or other heavy object, and planted in a favorable place on the bottom. Each fragment will grow into a complete sponge of harvestable size in two to three years.

Another asexual method involves the formation of **gemmules**. The gemmules, which are formed by aggregation of groups of cells, are hard-shelled bodies which germinate into new sponges. This method of reproduction is favored during periods of freezing temperature or drought.

Sexual reproduction involves the formation of ova and sperm from amebocytes. **Fertilization** is unusual in that sperm swept in with the water current are ingested by collar cells. The collar cells then fuse with the ovum and set the sperm free.

Protective Devices Used by Sponges

At first glance, a sponge resting on the bottom of the ocean resembles a defenseless blob waiting for anyone who is hungry. However, if you should pick up a sponge in your bare hands, you would quickly find it rather painful, especially if the organism is a glass sponge. The spicules are quite effective in causing intense discomfort by penetrating the soft tissue of anything that tries to handle them. Sponges also have disagreeable tastes and smells. They produce irritants which cause severe discomfort or even death to potential predators.

Commercial Sponges

The most obvious connection of sponges to man is the commercial sponge fishery. Sponges that are sold commercially have skeletons that consist only of the protein spongin. There are no limy or glass spicules. Commercial sponges can absorb 25–30 times their own weight of water. The main varieties of commercial sponges include Turkey cup, toilet, Zimocca, wool, velvet, yellow, grass, wire, and elephant's ear. Differences in quality depend on locality and bottom conditions. The best sponge grounds are in warm tropical and subtropical areas such as the Mediterranean, Gulf of Mexico, East Indies, the Sea of Japan, and the Philippines. The depth of commercial sponge grounds varies from shallow water to 600 feet.

The sponges are gathered by hard hat divers, hooking from the surface, or dredging. The best sponges are gathered by hard hat divers at about 100 feet. In the Mediterranean, sponges are taken from depths of 450–600 feet by dredges. This method destroys many valuable young sponges.

The sponge catch is left on deck to decay. After a few days, the tough outer skin is peeled off and the sponges are washed and dried. The dried sponges are sorted by size and stored for sale at auctions.

VOCABULARY

Amebocytes—amoeba-like cells in sponges that function in circulation and excretion.

Asconoid—the simplest type of body organization in sponges.

Asexual reproduction—reproduction without the joining together of two cells.

Budding—a type of asexual reproduction in which an outgrowth forms on the parent organism and later separates giving rise to a new organism.

Calcareous sponge—sponges whose spicules are composed of calcium carbonate.

Collar cells—flagellated cells in sponges that set up water currents.

Fertilization—the union of a sperm with an egg.

Flagellum—fine, long threads which project from a cell and move in an undulating fashion. Flagella are responsible for locomotion of small protozoans and reproductive cells.

Fragmentation—a type of asexual reproduction whereby pieces of an organism may break off and regenerate into whole organisms.

Gemmule—a reproductive body cell of a sponge enclosed by a tough, outer coating.

Glass sponges—sponges whose lattice-like skeletons are formed by fused spicules built of long fibers containing silicon.

Habitat—the place where an organism lives.
Mesoglea—a jellylike material between the two cell layers composing the body of certain organisms.
Osculum—an opening in the central cavity of sponges through which water leaves the animal.
Ostia—tiny openings through which water is drawn into the sponge's body.
Ova—female reproductive cells.
Pinacocytes—cells which cover the outside of the body of a sponge forming an epidermis.
Porocyte—a cell, shaped like a short tube, that extends from the surface of the sponge to the spongocoel and "guards" an incurrent pore.
Pseudopodia—"false feet" formed by extensions of cytoplasm. They serve as a means of locomotion and a way of surrounding and thereby absorbing food.
Sessile—the condition of being permanently attached to another object.
Sexual reproduction—reproduction involving the union of an egg and sperm.
Sperm—a male reproductive cell.
Spicule—the material forming the skeleton of certain sponges.
Spongin—fibers composing the skeleton of certain sponges.
Spongocoel—the central cavity in sponges.

Activity: **Sponge Structure**

Objective

To study the structure of some common sponges and to identify these sponges.

Materials

preserved sponges, 10% acetic acid solution, stereoscope or hand lenses, microscope, probe, slides, coverslips, sea water, wax pencils

Procedure

Four sponges have been chosen for your study today. They can be found in dishes on the supply table. The dishes are labeled A, B, C, and D respectively. You will notice that in the following investigation these four specimens are those used for various activities and questions. Consequently, when you are asked to answer a question about (or perform an activity using) sponge specimen A, you should also answer that same question for (or perform the experiment on) specimens B, C, and D. Since there is not enough space on these sheets to record all your observations and answers concerning specimens B, C, and D, you should use a separate sheet of paper.

Place a specimen of sponge A on a clean slide. Using your hand lens or a stereomicroscope examine the specimen. Name as many of the external structures as you can find. ______
Describe the **osculum.** ______
What does the position of this structure on the sponge body suggest to you about its function? ______

______

Cut sponge A longitudinally (up and down). Sketch the internal structure of the sponge in the space provided below and then label the **spongocoel.**

Place a small piece of tissue from sponge A in a drop of water on a slide. Tease apart the tissue using a probe, add a coverslip to the slide, and study the slide under 100X and 400X. Can you identify any of the cells present by their shapes? ______
Suggest a reason why some of these cells seem to have a very definite shape as opposed to other cells present in the specimen.

______

Make sketches of any cells that you are unable to identify.

Prepare a slide of sponge A by placing a small piece of tissue in a drop of 10% acetic acid on a clean slide. Add a coverslip to the slide and observe. Record your observations. ______
Was a new substance produced? ______ How could you tell? ______
What possible explanation could there be for the phenomenon you have just observed? (Hint: Remember skeletal structure.) ______

______

Now mount a piece of sponge A in sea water. Add a coverslip and observe the slide under the microscope. Do you see any changes occurring? ______
Keep your slides and label them appropriately.

After completing your experiments on specimens A–D, use your observations and the taxonomic key to identify sponges A–D. List your answers below.

KEY TO SELECTED SPONGES

1.A.	Structure of sponge simple; tubular to urn-shaped; pale tan to whitish; **spicules calcareous** (test with acetic acid)	Go to 2.
B.	Structure massive, fleshy, or spongy; encrusting or branching; color various; spicules **siliceous**	Go to 3.
2.A.	Sponges in form of branching, cylindrical, pale tubes	*Leucosolenia*
B.	Sponges in the form of little urns or vases, usually clustered, with fringe of spicules around the terminal osculum	*Grantia*
3.A.	Spicules smaller and conspicuously joined together by more or less **spongin** to form a network or a system of tracts	*Spongilla*
B.	Spicules irregularly scattered; considerable spongin is present; numerous low, upright tubules, each ending in an opening	*Halichondria*

Sponge A is ______. Sponge C is ______.
Sponge B is ______. Sponge D is ______.

VOCABULARY

Calcareous—sponges whose spicules are composed of calcium carbonate.
Osculum—an opening in the central cavity of sponges through which water leaves the animal.
Siliceous—made up of silica.
Spicules—the material forming the skeleton of certain sponges.
Spongin—fibers composing the skeleton of certain sponges.
Spongocoel—the central cavity in sponges.

Activity: Aggregation of Sponge Cells

Objective

To observe the aggregation of sponge cells.

Materials (per group of 2 students)

1 stender dish, 1 pair of forceps, 1 glass slide, 1 coverslip, 1 microscope, 1 living specimen of *Spongilla*

Procedure

Place a drop of freshwater on a clean slide. Grasp a small piece of living sponge with forceps and squeeze the sponge into the water drop until the sponge pigment is barely visible in the water. What is the purpose of this procedure?

______

The following steps must be carried out quickly (within 30 seconds). Discard the piece of sponge and remove any sponge fragments from the water drop. Carefully place a coverslip on the slide and examine it under low power using the microscope. Describe the distribution of cells under low power. ______

______

Switch to high power. Do you now see anything that you did not see when you were using low power? ______ If so, describe it. ______

______

After you have made careful observations of your slide, place it, with coverslip in place, into a stender dish of creek water. Five minutes later, remove the slide from the culture dish. *Dry the bottom surface of the slide and examine it under the microscope.* Record your observations in the table provided. Return the slide to the culture dish and gently slip the coverslip off the microscope slide. Propose a reason for removing the coverslip. ______

______

______

______

Re-examine the slide and record your observations at the intervals suggested in the table on the following page.

Now that you have finished collecting information about sponge reaggregation, summarize your observations in a paragraph.

Time	Observations on low power	Observations on high power	Is there any evidence of clumping? Describe.	Sketch of clumping
5 min.				
30 min.				
1 hr.				
2nd hr.				
3rd hr.				
4th hr.				
5th hr.				
2nd day, 1st hr.				
2nd day, 2nd hr.				
2nd day, 3rd hr.				
2nd day, 4th hr.				
2nd day, 5th hr.				
3rd day, 1st hr.				
3rd day, 2nd hr.				
3rd day, 3rd hr.				
3rd day, 4th hr.				
3rd day, 5th hr.				

CONCEPT C

Cells found within the bodies of coelenterates are more highly specialized than sponge cells. Coelenterates have two different types of body forms, the polyp and medusa.

Objectives

Upon completion of this concept, the student should be able:

a. To sketch the two body forms of coelenterates.
b. To list the three classes of coelenterates.
c. To describe nematocysts and the two factors required to cause discharge.
d. To describe locomotion in the coelenterates.
e. To describe feeding in hydrozoan and anthozoan polyps.
f. To discuss the importance of coelenterates to the ecosystem.
g. To discuss the economic importance of coelenterates.

THE COELENTERATES (PHYLUM CNIDARIA)

The coelenterates exist in two basic forms, the **polyp** and the **medusa** (Figure 1). Polyps are sessile, tentacled forms that remain in one place and trap animals on their tentacles. *Hydra* is an example of a coelenterate polyp. The medusae are umbrella-shaped animals that live up in the **water column**, moving by pulsations of their bell-shaped bodies. Their dangling tentacles serve to ensnare other animals on which they feed. The common jellyfishes are examples of a medusa.

In many cases, the medusa and polyp forms are parts of the life cycle of a single species. The polyps are generally sessile forms that reproduce asexually by **budding**. Medusae are sexually reproducing, planktonic forms. The life cycle of *Obelia*, a coelenterate, is an example of this situation (Figure 2). The existence of two vastly different forms fulfilling sexual and asexual roles in the life cycle of a single species is called **metagenesis**.

The phylum Cnidaria is divided into three classes: Hydrozoa, Scyphozoa, and Anthozoa.

Body Plan

The polyps and medusae are both built on the same basic plan. The body consists of inner and outer walls separated by a jellylike **mesoglea** (Figure 1). The basic shape is that of a barrel, the inside of the barrel being called the **gastrovascular cavity**. One end of the barrel is closed off. The outside surface of this end forms the **pedal disk** of the sea anemones. The medusa is like an inverted polyp. The closed end of the barrel forms the upper surface of the **umbrella**. The other end of the barrel is open, forming the mouth. The mouth is surrounded by one or more whorls of **tentacles**, each containing an extension of the gastrovasuclar cavity.

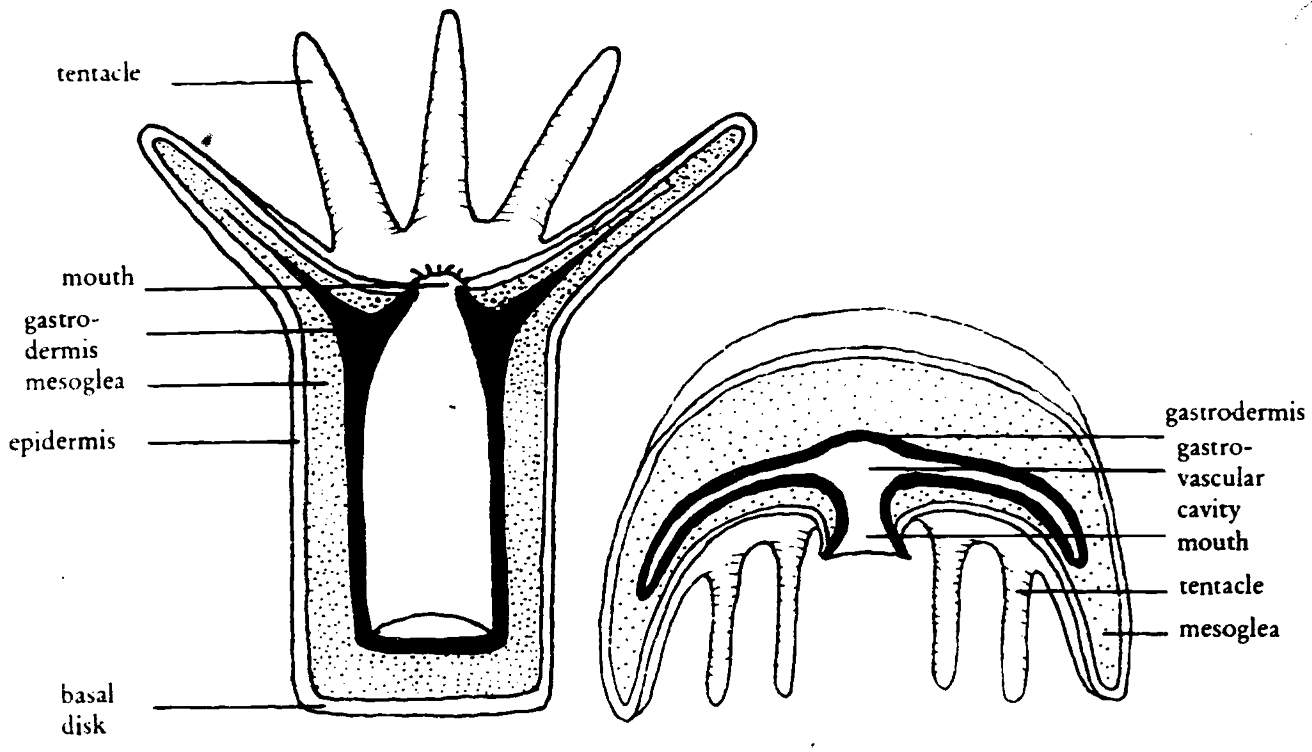


Figure 1. A, Polyp. B, Medusa.

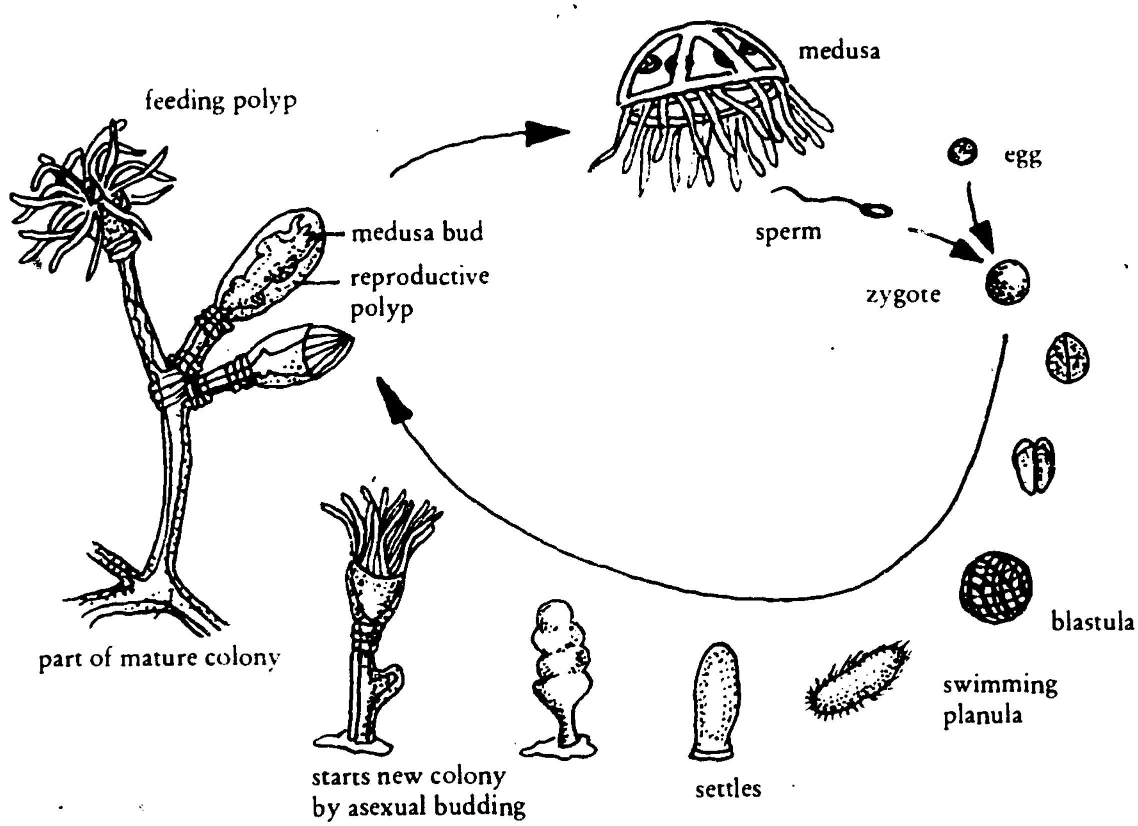


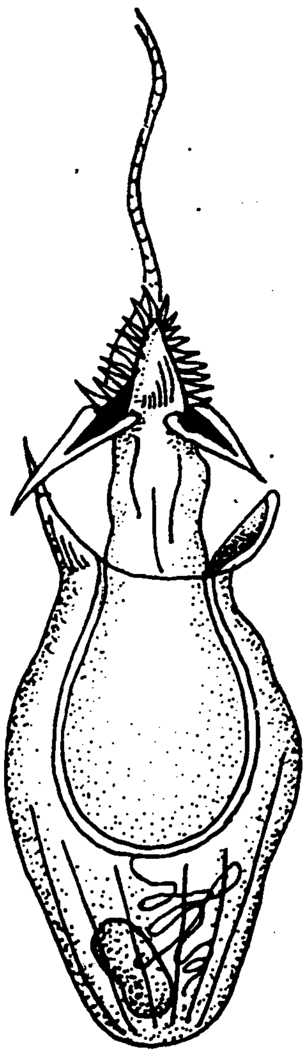
Figure 2. Life Cycle of *Obelia. Obelia* is a colonial hydrozoan.

Nematocysts

The tentacles of coelenterates possess certain structures found almost nowhere else in the animal kingdom. These are the **nematocysts.** Nematocysts are responsible for the painful stings inflicted by jellyfish.

An undischarged nematocyst consists of a bulb with a thread coiled inside it. It is contained within a cell called a **cnidoblast.** The cnidoblast possesses a bristle which acts as a trigger for discharge of the nematocyst (Figure 3A). When a prey animal or a swimmer brushes the bristle, the permeability of the nematocyst wall changes. The nematocyst swells with water and the resulting pressure causes the thread to explode from the capsule and hit the target organism (Figure 3B).

A.



B.

Figure 3. A, Undischarged Nematocyst.
B, Discharged Nematocyst.

The eversion of the nematocyst thread exposes the various end structures of the nematocyst. These can consist of adhesive ends, snares, or pointed barbed tips which penetrate the prey and inject powerful **toxins.** The toxins of some species, such as the Portuguese man-of-war, can cause severe pain in human beings. The pain can be so intense that the victim can be crippled and may drown.

Class Hydrozoa

Class Hydrozoa includes many common coelenterates that are easily overlooked. Included in this class are the hydroids. The hydroids, which are usually mistaken for seaweed, form branched polyp colonies of various sizes. The branched colonies consist of one or more types of individuals. The most animal-like members of the colony are the feeding polyps. All of the individuals of the colony are connected by a common gastrovascular cavity. The feeding polyps capture the food and partially digest it. They pass the resulting broth into the common gastrovascular cavity, whence it circulates throughout the entire colony. Various other members of the colony will pick out their share of the broth and digest it in intracellular vacuoles similar to those of protozoans. *Hydractinia* is an example of a hydroid that is found in coastal waters. Its polyp is specialized for feeding, reproduction, and fighting (Figure 4).

The medusae of the Hydrozoa are relatively small. They range from a centimeter to several centimeters in diameter. The lower margin of the umbrella usually projects inward to form a shelf called the **velum.** The gastrovascular cavity possesses the barrel-like shape of the polyp, but its structure is rather complex. Branching from the central stomach is a series of radial canals which, taken together, resemble the spokes of a wheel. These canals run down the sides of the umbrella to the margin. In the margin of the umbrella, or bell, they enter a ring canal which runs all the way around the lip of the bell.

The medusa moves by jet propulsion which is especially effective in species with a well-developed velum.

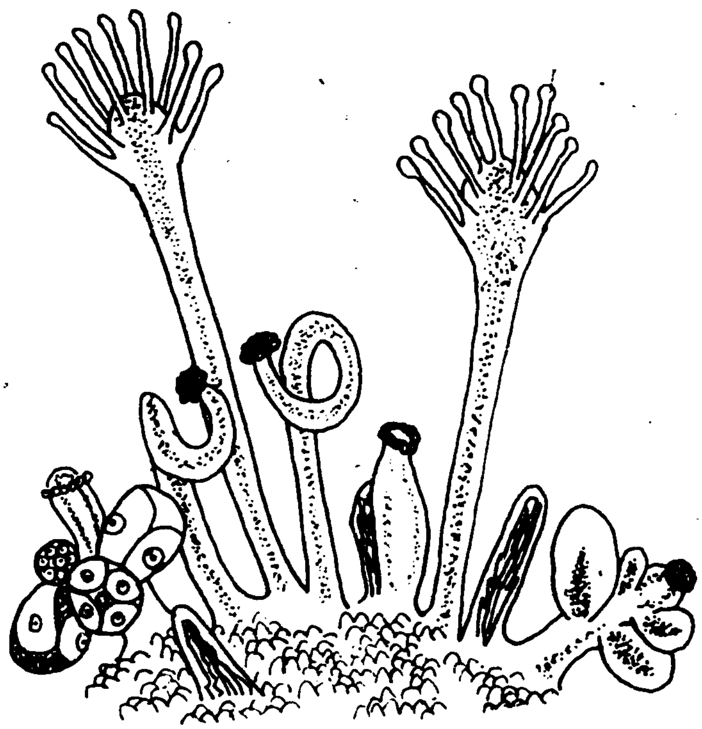


Figure 4. *Hydractinia.*

Class Scyphozoa

The Scyphozoan medusae are the large jellyfishes observed in ocean waters and tossed up on beaches. The polyp stage is restricted to a tiny **larval** form which is relatively insignificant. Scyphomedusae never have a velum which, along with their large size, separates them from the small velum-possessing hydromedusae.

Jellyfish feed on various small animals, from protozoans to fish or whatever other manageable creature is paralyzed by their nematocysts. Some have abandoned the use of tentacles in capturing food. They have become **plankton** feeders eating plankton trapped under the bell as the animal sinks. Mucus on the bell traps planktonic forms. The trapped plankton is removed from the bell by extensions of the mouth called **oral lobes.** The food is carried to the mouth along ciliated groves on the underside of the oral lobes. This is the case in *Aurelia,* a commonly studied jellyfish (Figure 5).

Reproduction is through production of eggs and sperm, usually by different individuals. The **zygote** forms a flat larva. The larva settles to the bottom to become a tiny polyp. Medusae are produced by division of this polyp into a pile of larvae. These lie stacked on top of each other like a pile of saucers. As each larva completes development, it breaks away and develops into an adult medusa.

Class Anthozoa

The anthozoans have no medusa stage anywhere in the class. They exist strictly in the polyp form which is capable of both sexual and asexual reproduction.

The anthozoan polyp is much more complex than the polyp stages of the other two classes. The mouth opens into a well-organized **pharynx** occupying much of the gastrovascular cavity. The cavity itself is divided into a series of **longitudinal** sections by partitions running its length. The partitions, called **septa,** have nematocysts along their edges (Figure 6). Sea anemones, corals, and sea pansies are among the organisms included in class Anthozoa.

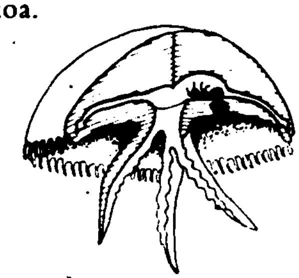


Figure 5. *Aurelia.*

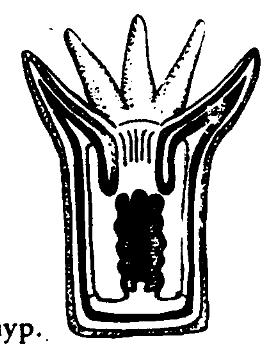


Figure 6. An Anthozoan Polyp.

Sea anemones are anthozoan polyps ranging from a centimeter to a meter or more in diameter. They appear as a heavy stalk crowned by a ring of tentacles. They live in coastal waters throughout the world, but are most abundant, varied, and colorful in the tropics.

Several species of sea anemones are selected as companions by hermit crabs. The hermit crab places an anemone on its shell and travels about with it attached. The anemone camouflages and protects the hermit crab from potential predators. In return, the anemone gets carried into new areas where it may find more prey to get trapped in its tentacles. It may also share the hermit crab's meal. As a method of protection, other crabs hold a pair of small anemones in their claws like boxing gloves.

The sea anemones eat various invertebrates which stumble onto the tentacles. Larger species can catch fish. The large anemones are sometimes aided in fishing by the existence of various small fish. These fish are immune to the toxin that can be injected by the nematocysts. They live in and around the tentacles of the sea anemone and probably act as bait for larger fish. When an animal is trapped by a group of tentacles, other tentacles join the initial ones, and all fold toward the mouth. The prey enters the anemone whole and is digested in the bag of the body. Some anemones feed by the use of cilia. Beating cilia set up feeding currents which entrap small organisms. These organisms are caught in the mucus found on the surface of the anemone. The feeding currents propel the entrapped organisms.

A common method of reproduction is called **pedal laceration.** As the anemone moves along, parts of the pedal disc are left behind to grow into new anemones. This is a form of asexual reproduction. The anemones may also reproduce sexually. **Gonads** may change sex with age in species that have both male and female reproductive organs.

Corals

The stony or madreporian corals form the great reefs and coral islands of the world. Coral reefs form local centers of high **productivity** in the deep sea, which is generally almost a desert compared to coastal regions.

The polyps of the corals strongly resemble sea anemones. However, the stony corals lay down a calcium carbonate skeleton. The polyp sits in a cup in this skeleton. The star coral, *Astrangia,* is found as small coral clumps attached to shells and other flotsam (Figure 7). You have no doubt picked up pieces of shell with stony lumps on them containing holes almost entirely filled with thin radiating septa. These are the skeletons of star corals. The fine walls of calcium carbonate fit into the walls forming the longitudinal partitions of the anthozoan gastrovascular cavity. In large colonial corals, the cups often run together. This is the case in the brain corals of the great reefs. In the brain corals, rows of cups are separated. Individual cups in a row are confluent (Figure 8).

The coral animals usually contain symbiotic algae which are important to the animals' existence. For this reason, most reef-building corals live in water no more than 300 feet deep. This is the greatest depth at which the symbiotic algae can carry on photosynthesis at a sufficient rate to supply the needs of the coral.

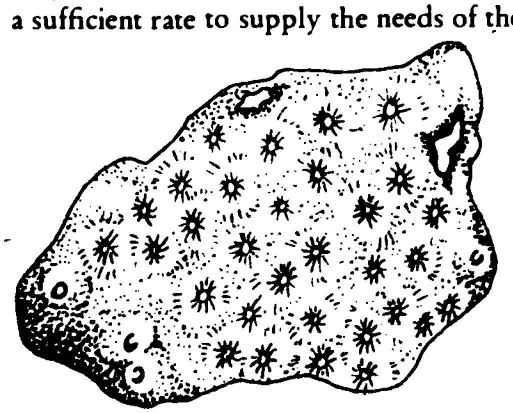


Figure 7. *Astrangia* (Star coral).

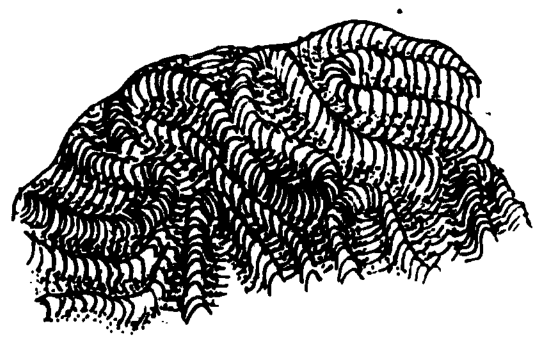


Figure 8. Brain Coral.

Coelenterates and Man

The corals are by far the most important of the coelenterates to mankind. The reef-building corals grow only in tropical and subtropical waters where the temperature never falls below 21°F. They have built islands and ring-shaped **atolls** throughout the Pacific Ocean on top of submerged volcanoes. Islands of coral and/or volcanic origin have been the sites of development of whole civilizations in the Pacific Ocean. In the Atlantic Ocean, the Bahamas and other tropical paradises are largely built of coral. The reefs, like oases in the vast desert of the tropical mid-ocean, have supplied food of great variety for the inhabitants of these islands. The diet of the early inhabitants of the islands was richly varied. Plants supplied the necessities of fresh green vegetables and the reefs supplied fresh animal protein of various kinds.

VOCABULARY

Asexual reproduction—reproduction without the joining together of sex cells.

Atoll—a type of coral reef that has an open lagoon in the middle.

Budding—a type of asexual reproduction in which an outgrowth forms on the parent organism and later separates giving rise to a new organism.

Cnidoblasts—a type of cell which contains a nematocyst.

Gastrovascular cavity—the central cavity of coelenterates.

Gonads—male and female reproductive organs in which sex cells are produced

Larva—an immature stage in the life of an animal.

Longitudinal—running lengthwise.

Medusa—the free-swimming life stage of a coelenterate.

Mesoglea—a jellylike material between the two cell layers composing the body of certain organisms.

Metagenesis—two different forms of an organism which fulfill both sexual and asexual roles in its life cycle.

Mucus—a slimy lubricating and cleansing secretion.

Nematocysts—stinging cells found in the coelenterates.

Oral lobes—extensions of the mouth used for removing trapped plankton from the bell.

Pedal disk—a flattened area located at the aboral end of the body of certain coelenterates. It is used for attachment.

Pedal laceration—a form of asexual reproduction in which portions of the pedal disk develop into new organisms.

Pharynx—an area within the gastrovascular cavity.

Plankton—small plants and animals floating in the upper layers of the water column.

Polyp—the bottom-dwelling form of coelenterates which is attached to a hard surface.

Productivity—amount of organic material formed in excess of that used for respiration. It represents food potentially available to consumers.

Reef—a ridge of rocks, sand, or coral at or near the surface of the water.

Septa—partitions found in the gastrovascular cavity.

Sessile—the condition of being permanently attached to another object.

Tentacles—a long appendage, or "feeler", of certain invertebrates.
Toxin—a poisonous substance.
Umbrella—refers to the medusa body form of certain coelenterates.
Velum—the flat muscle band around the edge of a hydrozoan jellyfish.
Water column—the area from the water surface to the bottom.
Zygote—a fertilized egg resulting from the union of sperm and an egg.

Activity: General Behavior and Feeding Behavior of *Hydra*

Objectives

To observe some of the general behavior patterns of hydra.
To investigate the feeding process used by hydra.
To investigate the firing action of nematocysts.

Materials (per group of 2 students)

specimens of living hydra attached to substrate, 1 watch glass (or small dish), pond water, brine shrimp larvae, 0.5% methylene blue, 1 medicine dropper, 2 microscope slides, coverslips

Procedure

I. General Behavior of *Hydra*

a. Obtain one healthy hydra, attached to a piece of substrate, from the available cultures and place it in a small volume of pond water. Remember that these are fresh water organisms and not marine. Observe them in an undisturbed state for several minutes and record the behavioral patterns seen tentacle movement, body bending, etc.) ____________

____

____

b. With a needle or fine forceps, dislodge the basal disk of the hydra and watch its reattachment. (If you cannot locate the basal disk, consult your biology textbook for an illustration of a hydra.) Do the tentacles seem to be adhering to the bottom of the dish? __________ What might account for this? ______________________________

____

Repeat the dislodgement procedure several times to see if you can determine how many distinct behavioral patterns are involved. Record the time of dislodgement and the time to reattach completely. ______________ Did you observe them somersaulting? __________

II. Feeding Behavior of *Hydra*

After your animal has reattached to the substrate, obtain a drop of a suspension of *Artemia* (brine shrimp) larvae. Make sure that these larvae are suspended in fresh water at the time of feeding since they have been hatched in salt water. Carefully place the tip of your medicine dropper near the expanded tentacles of the hydra, taking care not to cause your experimental animal to contract. Gently release the *Artemia* over the hydra and observe the results. What happened when the larvae contacted the tentacles? ______________

____

____

Record your observations in a logical manner including time of first contact of the larvae with the tentacles, the time of mouth opening and the time of ingestion of the larvae.

____

____

____

Do animals that have already fed on some larvae take a longer or shorter time to respond? __________ How long does it take for a single larva to cease struggling following initial contact with the tentacles? ______________
Does this time vary depending on which part of the larval body contacted the tentacle first? ______________

Observe carefully what happens as the larva nears the mouth region of the hydra. Does the rate of mouth-opening increase as the prey nears the mouth? __________ How is the prey ingested and what is the behavioral sequence undergone by the tentacles during feeding? Record the times at the beginning and end of each behavioral sequence. Do these times vary for individual tentacles on the same animal? ______________

____

Before final ingestion remove several *Artemia* that appear to have made good contact with the hydra's tentacles. Place these on a clean glass slide, flatten under a coverslip, and observe under the high power of your microscope. Can you see any small seed-like structures at the ends of threads which appear to have either penetrated the *Artemia* or wrapped around some of the bristles on its appendages? __________ These are the **nematocysts** that are characteristic of the phylum Cnidaria. The toxin released from some of the nematocysts was responsible for the paralysis and death of the larvae that you observed. You may have trouble seeing the nematocysts unless the larvae are perfectly oriented on your slide. If you do encounter trouble, add a drop of 0.5% methylene blue on the larva and replace the coverslip. Flatten the preparation and again observe under the high power objective. Look especially at the appendages since they often make first contact with the hydra's tentacles.

After you have seen the fired nematocysts in the *Artemia*, flatten a whole hydra or preferably some of its tentacles under a coverglass. Add a drop of methylene blue. Can you see the nematocysts firing and taking up the stain? A drop or two of distilled or tap water may accelerate the nematocyst discharge. Describe the firing action of the nematocysts. ______________

____

VOCABULARY

Basal disk—structure which anchors the hydra to a substrate.
Larvae—immature stages in the life of an animal.
Nematocysts—stinging cells found in coelenterates.
Substrate—a surface upon which an organism attaches.
Tentacle—a long appendage, or "feeler", of certain invertebrates.

CONCEPT D

The amount of specialization shown by the ctenophores indicates that the group is clearly distinguishable from the coelenterates.

Objectives

Upon completion of this concept, the student should be able:

a. To list three characteristics of ctenophores which distinguish them from the coelenterates.
b. To explain the function of colloblasts.
c. To recognize and identify the three ctenophores studied when presented with illustrations of various organisms.

THE CTENOPHORES (PHYLUM CTENOPHORA)

Another group of organisms that can be collected from the Gulf of Mexico using a dipnet or seine is the ctenophores. The ctenophores or comb jellies, as they are often called, seem related to the coelenterates at first glance. This observation is easily explained since ctenophores have a net-like nervous system, a large **gastrovascular cavity** with the absence of other body cavities, and apparent **radial symmetry.** When these organisms are examined more closely, there are sufficient differences to place the ctenophores in a completely separate phylum from the coelenterates.

Since the ctenophores do not possess **nematocysts,** one might think that it would be difficult for these organisms to obtain food. This is not the case. The ctenophores possess structures called **colloblasts** that are able to capture food for the animal (Figure 1A). The colloblasts are usually located on the **tentacles.** These peculiar adhesive cells secrete a sticky substance that is useful in catching prey.

The tentacles, if present, are usually internal and not radially arranged. They function in trapping planktonic organisms with the aid of the colloblast cells. In this process the tentacles are extruded and then pulled within, once the prey has been captured. The food is removed and quickly swallowed.

The ctenophores move very slowly and smoothly through the water. This movement is possible because of the structure and function of eight **longitudinal** rows of **comb plates** or ctenes (Figure 1B). The comb plates are formed from fused **cilia.** During movement, the comb plates beat in rhythm toward the **aboral** end (opposite end from the mouth) of the ctenophore. This beating is under the control of the nerve net pending stimulation by a unique structure called a **statocyst** (Figure 1C). The statocyst is a sense organ on the aboral

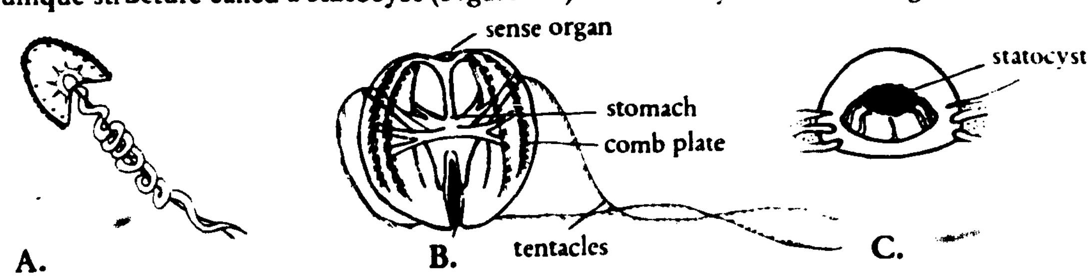


Figure 1. Ctenophore Structures. A, Colloblast. B, *Pleurobrachia* showing comb plates. C, Statocyst.

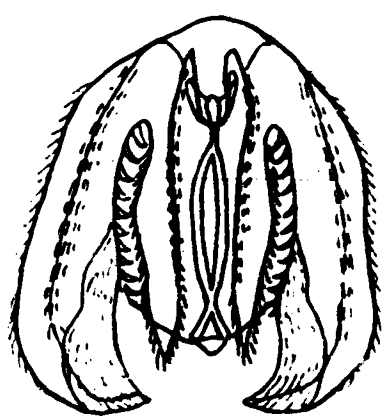
end of the ctenophore. It consists of a tiny secreted pebble resting on four tufts of cilia. Each ciliary tuft possesses a pair of ciliated bands running to the aboral end of a comb plate row. If the ctenophore is pushed over in one direction, the statocyst pebbles apply more pressure on the cilia of that side. This greater pressure causes impulses which generate a more rapid beating of that comb plate row. This increased beating gives the needed push on the affected side to return the organism to its original position. A ctenophore may also reverse the beat of the comb rows to back away from an object in its path.

Ctenophores are **luminescent** creatures. The light that is observed radiates from canals under each row of comb plates. It has a rather spectacular bluish tint that, if seen, will not quickly be forgotten.

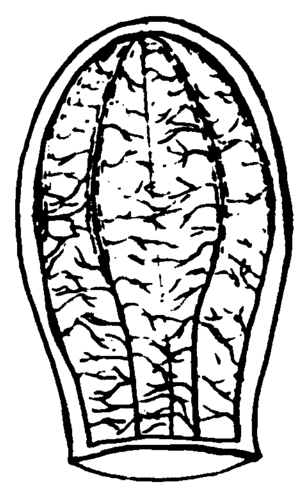
Ctenophores are **carnivores**. Since ctenophores may consume an enormous quantity of food in a very short period of time, they can become a serious predator of commercial species of marine life. A single ctenophore may easily consume over 125 oyster **larvae** at one time. In addition to oyster larvae, ctenophores prey on other planktonic forms such as larvae of fish, shrimp, crabs, clams, and other valuable species. A very large population of ctenophores may be so destructive that certain links in the marine food chain disappear for a very long period of time.

Pleurobrachia is probably the most common ctenophore (Figure 1B). Observing the figure, you can note the very large tentacles which are not radially placed. This organism is usually not found in the Mississippi Sound and adjacent Gulf of Mexico since it prefers colder water.

Two species found along the Gulf Coast in profusion are *Mnemiopsis* and *Beroë*. *Mnemiopsis* is fairly large and is often overlooked because of its transparency (Figure 2A). It can easily be recognized by the two large lobes that make up most of its bulk. *Beroë* is about the same size as *Mnemiopsis*, but is somewhat more flattened and lacks lobes and tentacles (Figure 2B). *Beroë* or the sea walnut, as it is sometimes called, is usually more common in the winter; whereas, *Mnemiopsis* is the more common species during the summer.



A.



B.

Figure 2. Ctenophores. A, *Mnemiopsis*. B, *Beroë*.

VOCABULARY

Aboral—the side opposite the mouth.
Carnivore—an animal which preys on other animals.
Cilia—tiny, hairlike projections; used for locomotion in some organisms.
Colloblast—an adhesive cell found in the tentacles of ctenophores.
Comb plates—rows of long, fused cilia which are used for locomotion by ctenophores.
Gastrovascular cavity—the central cavity of coelenterates.
Larva—an immature stage in the life of an animal.
Longitudinal—running lengthwise.
Luminescent—light emitted from organisms by physiological processes, chemical action, friction, electrical, and radioactive emissions.
Nematocyst—stinging cells found in coelenterates. These specialized cells are used for trapping food.
Radial symmetry—a body plan in which a cut lengthwise through the middle in any direction produces two identical halves.
Statocyst—the balancing organ of the ctenophores.
Tentacle—a long appendage, or "feeler", of certain invertebrates.

CONCEPT E

The marine species of polychaetes possess numerous sensory structures. They serve as food for other organisms in the marine environment.

Objectives

Upon completion of this concept, the student should be able:

a. To describe the general body structure of a polychaete.
b. To list the scientific names of two of the polychaetes studied.
c. To explain the process by which the clamworm makes its tube.
d. To discuss the importance of polychaetes to the ecosystem.

THE ANNELIDS (PHYLUM ANNELIDA)

The world of marine worms has been known to man for as long as he has lived along the shores of salt waters. Perhaps the best known class of worms living in the sand and mud flats washed by the tides is the polychaetes (Class Polychaeta). This particular class contains over 5000 marine species.

Polychaetes are close marine relatives of terrestrial earthworms. The polychaetes possess certain characteristics that are common to all members of phylum Annelida. Some of these characteristics include: (a) body divided into segments, (b) body cavity separated from the digestive tube, (c) "brain" is on the **dorsal** side of the **anterior** end of the worm, (d) nerve cord runs throughout the body on the **ventral** side, (e) a **closed circulatory system** is present, and (f) the body wall contains circular muscles, those that go around the body, and longitudinal muscles, those that go up and down the body. Polychaetes typically have paired bristle-like **appendages** on each segment ("polychaete" means many-bristled).

Along the sides of the body are fleshy paddle-like lobes, filaments, or other paired structures which may be used for swimming, burrowing and/or respiration, depending on the species (Figure 1). The bristles have a great variety of shapes and are often used to distinguish one species from another (Figure 2). Polychaetes live in many ways. They live as tube dwellers that trap and filter their food, and sometimes as nomadic predatory animals feeding on other soft-bodied creatures. Nearly all polychaetes have varying combinations of **tentacles**, antennae, cirri, and **palps** concentrated near their anterior end that provide acute senses of taste and touch. Most polychaetes have at least one pair of these structures on the roof of the head.

Sexes are usually separate. **Eggs** and **sperm** are shed freely in the water, sometimes in response to temperature change, but often cyclically in tune with the tides. The eggs hatch into **larvae** which drift with the currents for a varying number of days before settling to the bottom and developing into adult worms. At least 80 species of polychaetes are known from the Mississippi Sound but there are probably many more yet to be discovered. We will mention only a few of these polychaetes in the following sections.

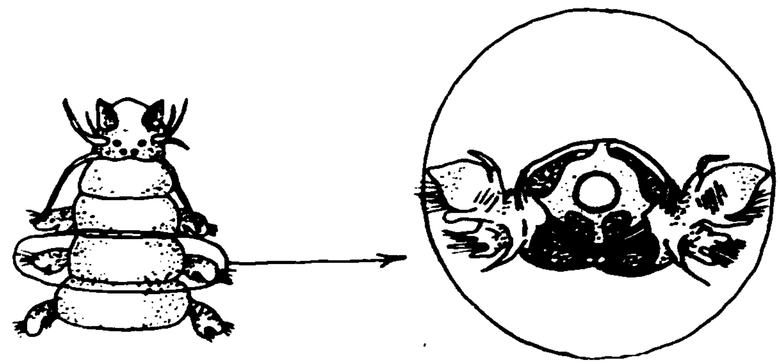


Figure 1. Fleshy Lobes Along the Body of an Annelid.

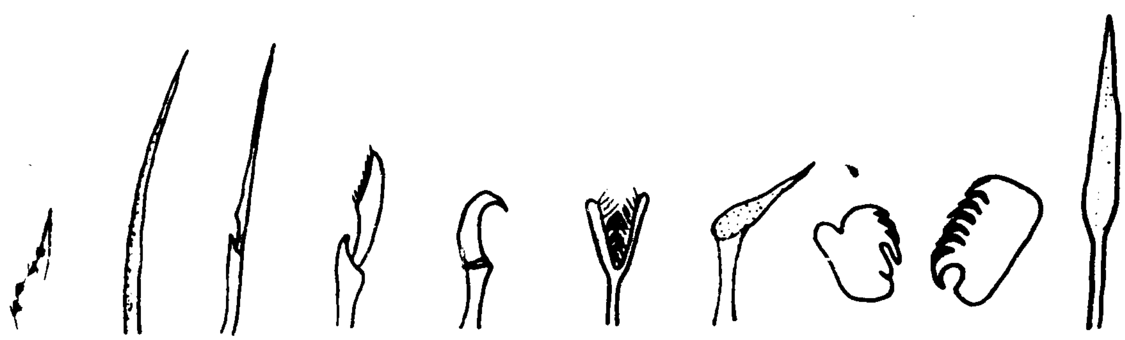


Figure 2. Variety of Bristle Shapes.

The Parchment Tube Worm

The creamy-white parchment tube worm, *Chaetopterus*, lives in a two-foot-long, U-shaped tube of self-manufactured parchment (Figure 3). The openings to these tubes are located at the surface of mud flats. *Chaetopterus* uses its fan-shaped parapodia to propel currents of water past its body in the tube. Water is sucked in at one end of the tube, bringing oxygen and plankton (food material), while wastes are discharged at the other end of the tube. These tubes can be seen dotting the bottom of the Sound at low tide. The 1?-minute feeding cycle of *Chaetopterus* includes water filtration and subsequent ejection of particulate matter.

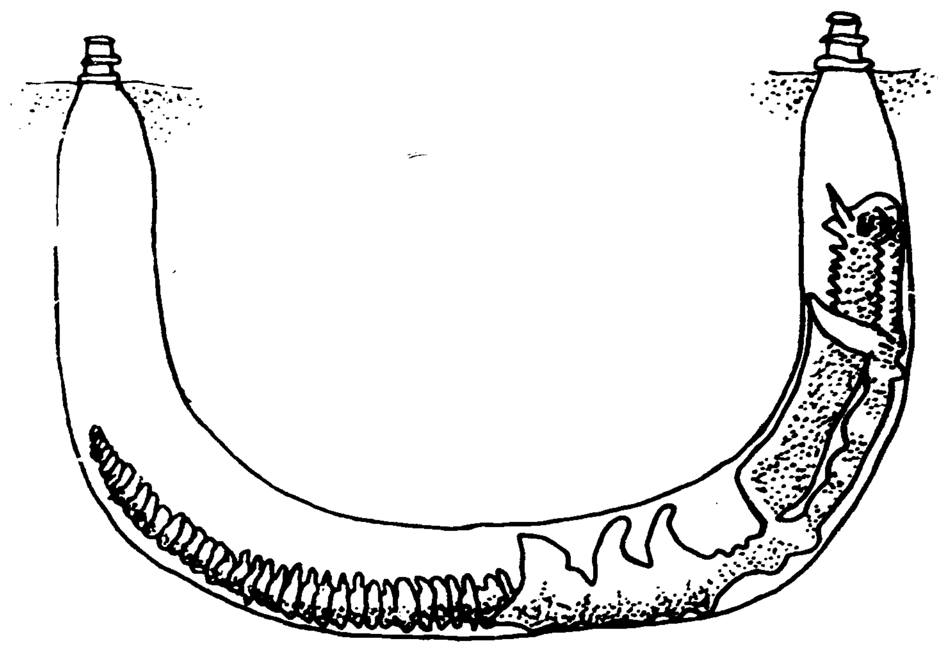


Figure 3. *Chaetopterus* in its Tube.

The Clamworm (Sandworm)

Nereis, the clamworm, (Figure 4A) lives in the sand in tubes where characteristic casts can be readily recognized. The tubes are made by the secretion of a sticky **mucus** from glands along the body. The mucus hardens quite rapidly, at the same time incorporating grains of sand from the environment. This flexible tube fits the worm so closely that, using its bristle-like spines, it can move within it and out of it with considerable speed. Since the clamworm's habit is to leave its burrow at night, it is at this time that the worm becomes prey to certain fish which prod it out of the sand.

Like other polychaetes, the clamworm's head has special sense organs consisting of two dorsal tentacles, a pair of ventral taste organs, four eyes, and four sense organs around the mouth. The mouth has a reversible **proboscis** with a few sets of spines, and ends with two dark-brown, cow-horn-shaped jaws that can bite vigorously. Depending on the age and size of the worm, there may be a considerable number of uniform segments behind the head. The last segment bears a pair of trailing, short, string-like sense organs. New segments are always added just in front of this terminal segment.

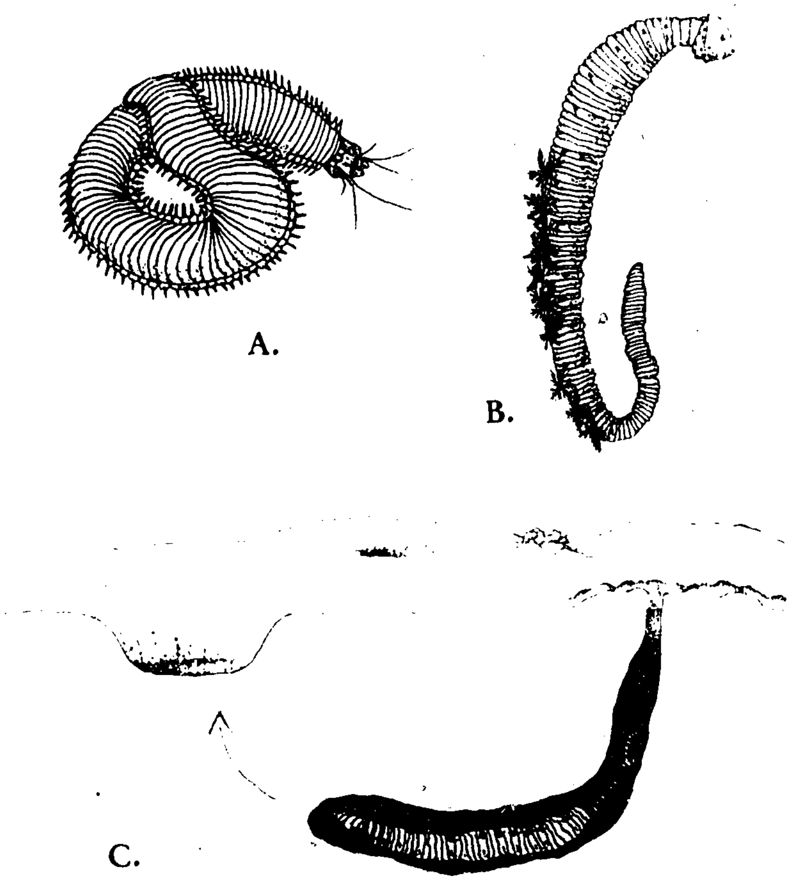


Figure 4. A, *Nereis*, (Clamworm). B, *Arenicola* (Lugworm). C, *Arenicola* in its Burrow.

The Lugworm

Arenicola, the lugworm, (Figure 4B) is like the earthworm in that it is a burrower. The lugworm can attain a length of 15–20 cm. It lives well below the surface in J-shaped burrows situated below or just above the low tide mark (Figure 4C). Its burrow is lined with mucus which prevents collapse of the burrow. *Arenicola* feeds by extracting organic matter from fine sand and debris that it takes in as it burrows along.

The Trumpetworm

Pectinaria gouldii, the trumpetworm, (Figure 5A) is a deposit feeder. This animal is called the trumpetworm because it fashions a cone-shaped tube of a single layer of carefully fitted sand grains cemented together with mucus. The worm carries its trumpet around, large end first, as it burrows through the sediment. *P. gouldii* digs with a row of golden setae which surround the head.

The Ragworm

Diopatra cuprea or ragworm is found in sheltered bays and beaches. This worm constructs a vertical tube which may extend 30 centimeters into the sediment although the animal itself seldom exceeds 10 centimeters in length. Several centimeters of tube extend above the sand. This portion of the tube is decorated with twigs, shell fragments, and other debris (Figure 5B). *D. cuprea* is a scavenger; it extends its body part way out of the mouth of its tube to search for food. The tube itself may serve as a giant filter to trap tiny, drifting plants and animals. The body of the ragworm is brown to iridescent green in color. The anterior end is provided with many pairs of gills, each one resembling a miniature red fir tree, and there are seven antennae on the head.

The Feather Duster Worm

The feather duster worm, *Hydroides*, can be found near the barrier islands in the Mississippi Sound (Figure 5C). These worms build a calcareous tube attached to hard substrates such as rocks, dead shells, and shipwrecks. The feather dusters have a crown of colorful tentacles or gills which they extend from the tube to trap drifting plankton for food. If disturbed, the worm quickly withdraws into the tube and covers the opening.

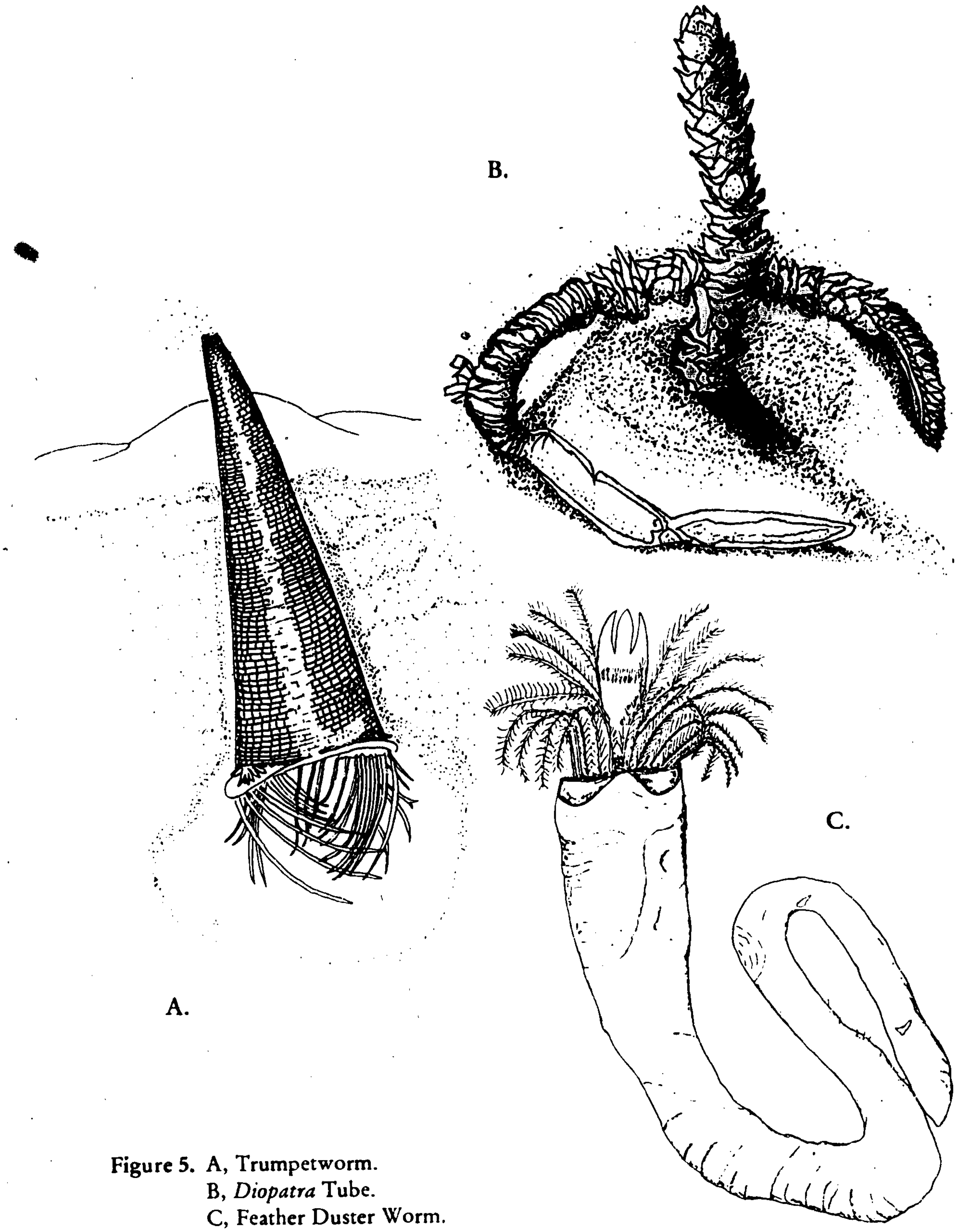


Figure 5. A, Trumpetworm.
B, *Diopatra* Tube.
C, Feather Duster Worm.

VOCABULARY

Anterior—front part of an animal.
Appendage—an outgrowth of the body of an animal.
Calcareous—composed of calcium carbonate.
Cirri—appendages used for scooping plankton from the water.
Closed circulatory system—one in which blood is confined to tubes throughout its course from the heart and back to the heart.
Dorsal—the topside of an organism.
Egg—a female reproductive cell.
Larvae—immature stages in the life of an animal.
Mucus—a slimy lubricating and cleansing secretion.
Mud flat—a level tract of land at little depth below the surface of water, or alternately covered and left bare by the tide.
Palp—a type of sense organ found on the "head" region of polychaetes.
Parapodia—the segmental appendages in polychaete worms that serve in breathing, locomotion, and creation of water currents.
Proboscis—a tubular extension used in feeding.
Setae—bristles on the polychaete worm body that are usually used in locomotion.
Sperm—a male reproductive cell.
Tentacles—a long appendage, or "feeler", of certain invertebrates.
Ventral—the underside of an organism.

Activity: How Does *Nereis* React to a Changing Environment?

Objective

To investigate the response of a marine worm to a change in its physical environment.

A very basic characteristic of animals is their ability to respond to a change that might occur in their environment. This ability to respond permits the animal to function in a much greater range of habitats and to survive through extreme environmental changes. Some of the responses are very easily detected, others are harder to detect. A change in temperature will usually cause some sort of response in most organisms.

In this experiment we will use *Nereis,* also called the clamworm, as our test organism. The dorsal blood vessel of the clamworm fills and empties once for each contraction of the worm's aortic arch series or elastic blood vessels. This provides an excellent mechanism for studying the "pulse rate" of the worm. The dorsal blood vessel can be seen as a dark wavy line under the skin and it disappears when emptied by the action of the aortic arches. You will determine the effect of different temperatures on the "pulse rate" of the clamworm. Before we begin the experiment, let's make some predictions. What will happen to the clamworm's pulse rate when we increase the temperature? ________________
What if we lower the temperature of the water? ________________.

Materials (Per group of 2 students)

1 *Nereis* specimen, 1 hand lens, 1 thermometer, crushed ice, warm water culture dishes, Instant Ocean® (substitute for sea water).

Procedure

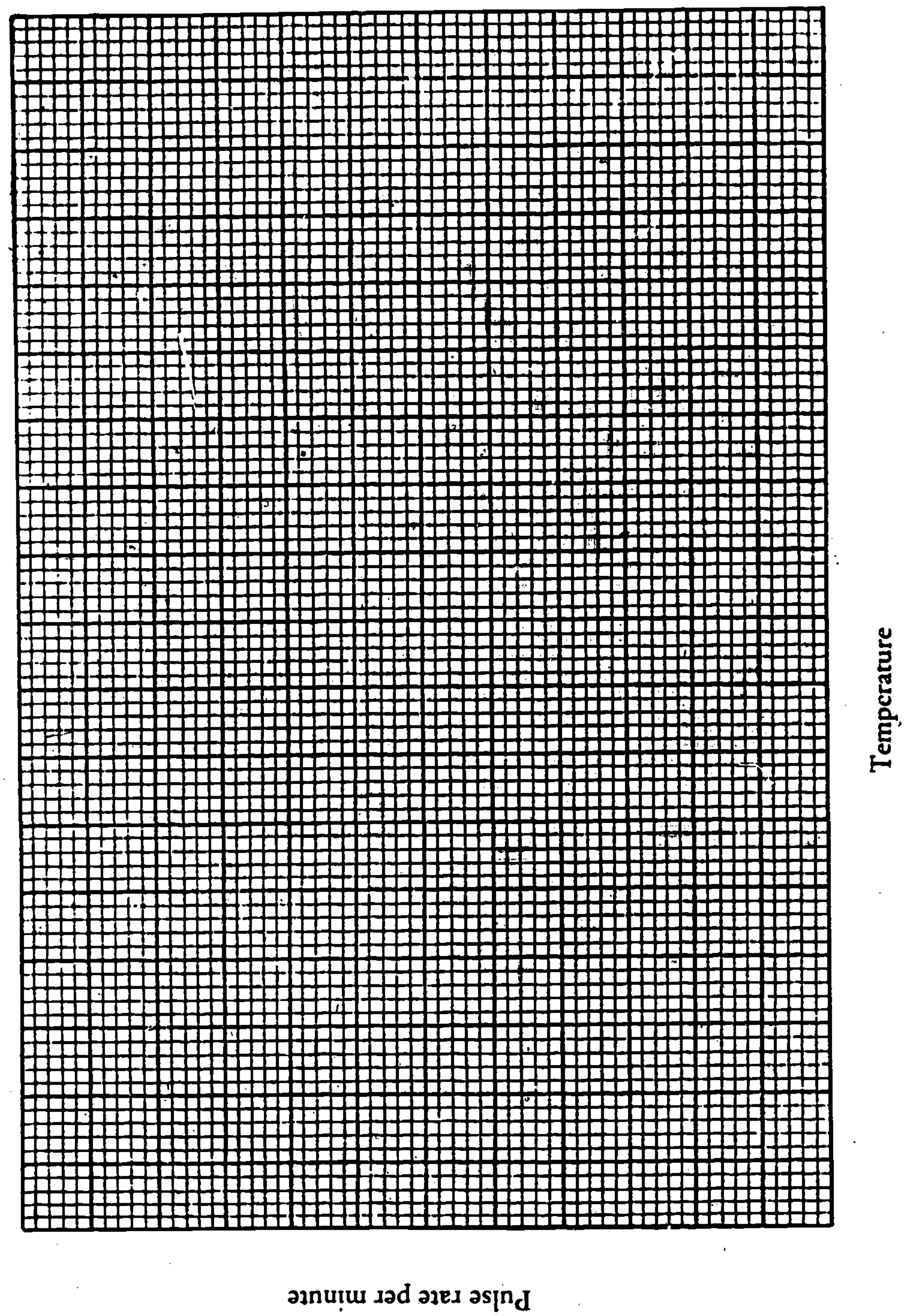
Fill a culture bowl with sea water at room temperature. (If you use Instant Ocean® as a substitute for sea water, follow instructions on the package for its preparation). Determine the temperature of the water using the thermometer and record that temperature in the data table. Place a specimen of *Nereis* in the dish. Make three measurements of "pulse rate per minute" of the worm. Record this information in the data table.

After completing the pulse rate count for room temperature, you should repeat the experiment at a warm temperature and a cold temperature. Heat some water to a temperature 10–20°C warmer than room temperature. Cool the water with crushed ice to a temperature 10–20°C cooler than room temperature. In each case change the water in the culture bowl and use first the hot then cold water. After introducing the hot or cold water, allow the experiment to set for a few minutes to allow for complete temperature equalization. Check the actual temperature of the water using a thermometer and then complete the pulse rate count three times at each temperature.

Data Sheet

		Pulse rate per minute			
	Actual temp.	Trial 1	Trial 2	Trial 3	Average
Room temperature					
10–20°C warm than room temp.					
10–20° cooler than room temp.					

After you have finished this experiment, complete the following graph.


Temperature
Pulse rate per minute

Extending Your Thoughts

Why is it important for an organism to be able to adapt to changing environmental conditions?______________________________________

Do you think that other worms would behave in the same manner as *Nereis?*__________ Design an experiment that will enable you to find out if the answer you just gave is correct. What worm(s) are you going to use in the experiment?____________________

Why must we be careful about stating our results from this experiment?______________

How can we provide better biological data concerning an investigation of this nature?_____

VOCABULARY

Aortic arch—large, muscular tubes which alternately contract and relax, keeping the blood flowing.
Dorsal—the topside of an organism.
Environment—the surroundings of an organism.
Habitat—the place where an organism lives.

Activity: Oxygen Consumption by Marine Worms

Objective

To study oxygen consumption by marine worms, using *Nereis* as the experimental organism.

Materials (per group of five students)

1 gallon of sea water or Instant Ocean®, 6 live clamworms, 2 one liter jars with lids, 1 kit for dissolved oxygen test

Procedure

In this investigation we will determine the rate of oxygen consumption by *Nereis* over a given period of time. It is your responsibility to develop a table that is suitable for recording your observations and data. Take a few minutes to read the rest of the experiment and design your table on a separate sheet of paper.

Weigh six specimens of *Nereis*. What problems did you have in weighing these worms?______________________________________

It is likely that the problems occurred due to lack of experience in using a balance. If you still do not understand the correct procedure for using laboratory balances, ask your teacher for assistance.

Pour approximately two liters of the sea water into a gallon jar and splash the water back and forth in the jar. What is the purpose of such agitation?____________________

____

Determine the temperature of water in the gallon jar. ________ Fill the first liter jar to overflowing with water from the gallon jar. Cap the jar well. What differences might exist between a capped jar filled with water and an uncapped jar filled with water from the same source?____

How could you definitely find out?____

Carefully add water from the same gallon jar to fill the second liter jar to overflowing. Place *Nereis* specimens in the second jar and cap it well.

Obtain a dissolved oxygen testing kit from the supply table and read the instructions included in the kit. From your reading, why do you think dissolved oxygen (DO) level is so important to marine and freshwater organisms?

____

____

Can you think of any ways to change the amount of DO in a water sample? List them.

____

____

What would happen to the dissolved oxygen content of a water sample if we raised the temperature of the sample?____

____

Using your DO kit, check the amount of dissolved oxygen present in another sample of sea water from the gallon jar. Assume that the amount of dissolved oxygen in this sample is equal to that in both liter jars at time "zero".

After one hour, determine the oxygen content of both jars. Use the first jar to correct the readings of the second jar, the one containing the worms.

Extending Your Thoughts

1. Based on your observations and data collected, what would you predict about the amount of oxygen consumed by other animals?____________________________

   ____

2. Why must *Nereis* and other animals consume oxygen? Why can't animals use carbon dioxide, like plants?____

   ____

After doing some background reading, on a separate sheet of paper write a paragraph explaining what you found out about the role of oxygen in an animal's body.

CONCEPT F

Mollusks are extremely variable in shape and size. Oysters are the most important mollusk in the Mississippi coastal economy even though several other mollusks are used as food sources.

Objectives

Upon completion of this concept, the student should be able:

a. To name at least five types of mollusks.
b. To describe the general characteristics of mollusks.
c. To discuss the importance of mollusks to the ecosystem.
d. To discuss the economic importance of mollusks.

THE MOLLUSKS (PHYLUM MOLLUSCA)

Mollusks are soft-bodied invertebrates that usually have a chalky shell into which the soft body can withdraw during times of danger. There are over 80,000 species, the majority of which are marine, with some living in fresh water and others on land. They include slugs, snails, limpets, whelks, oysters, clams, and scallops, as well as the shell-less and attractively colored sea slugs. The squid and octopus, which are exclusively marine, are set apart from the rest of the mollusks by their agility and well-developed eyes. Mollusks are exceedingly diverse in outward appearance, not only with respect to the shell but also the soft parts of the bodies. Mollusks date back to precambian times, 600 million years ago, and because their shells are readily preserved fossils, they are of great importance to geologists.

Fossil evidence indicates that the first mollusks were marine in origin and their larvae were undoubtedly trochophores like the larvae of **annelids**. These larvae are top-shaped with a tuft of sensory **cilia** at the apex and pre-oral and post-oral ciliary bands which serve to rotate the body and also collect microscopic particles of food.

The shells of mollusks vary from one piece in the gastropods to two shells in the bivalves and eight **dorsal** plates in the chiton shells (Figure 1A). Sea slugs and some terrestrial slugs have no shells. The mantle, a thin membrane, covers the internal organs which are concentrated in what is called the visceral hump. The gills, respiratory organs of the aquatic mollusks, are located in the mantle cavity. Cilia on the gills maintain a flow of water through the mantle cavity. A sense organ called the osphradium, located on the margin of each gill membrane, tests the water for turbidity and contamination. A gland called the **hypobrachial gland** produces a secretion to consolidate any sediments drawn into the cavity. The anus, kidney, and genital opening are associated with the exhalent current which carries waste as well as reproductive cells to the exterior.

The evolution of present day mollusks can be traced from a **bilaterally symmetrical** mollusk with an uncoiled shell, a foot with a broad sole and a definitive head, both covered by a shallow mantle cavity. It is assumed that this ancestral mollusk resembled the present day "living fossil" called *Neopolina* (Figure 1B). This animal has a limpet-like shell, a foot whose sole is circular in outline and separated from the shell by a broad groove, and a

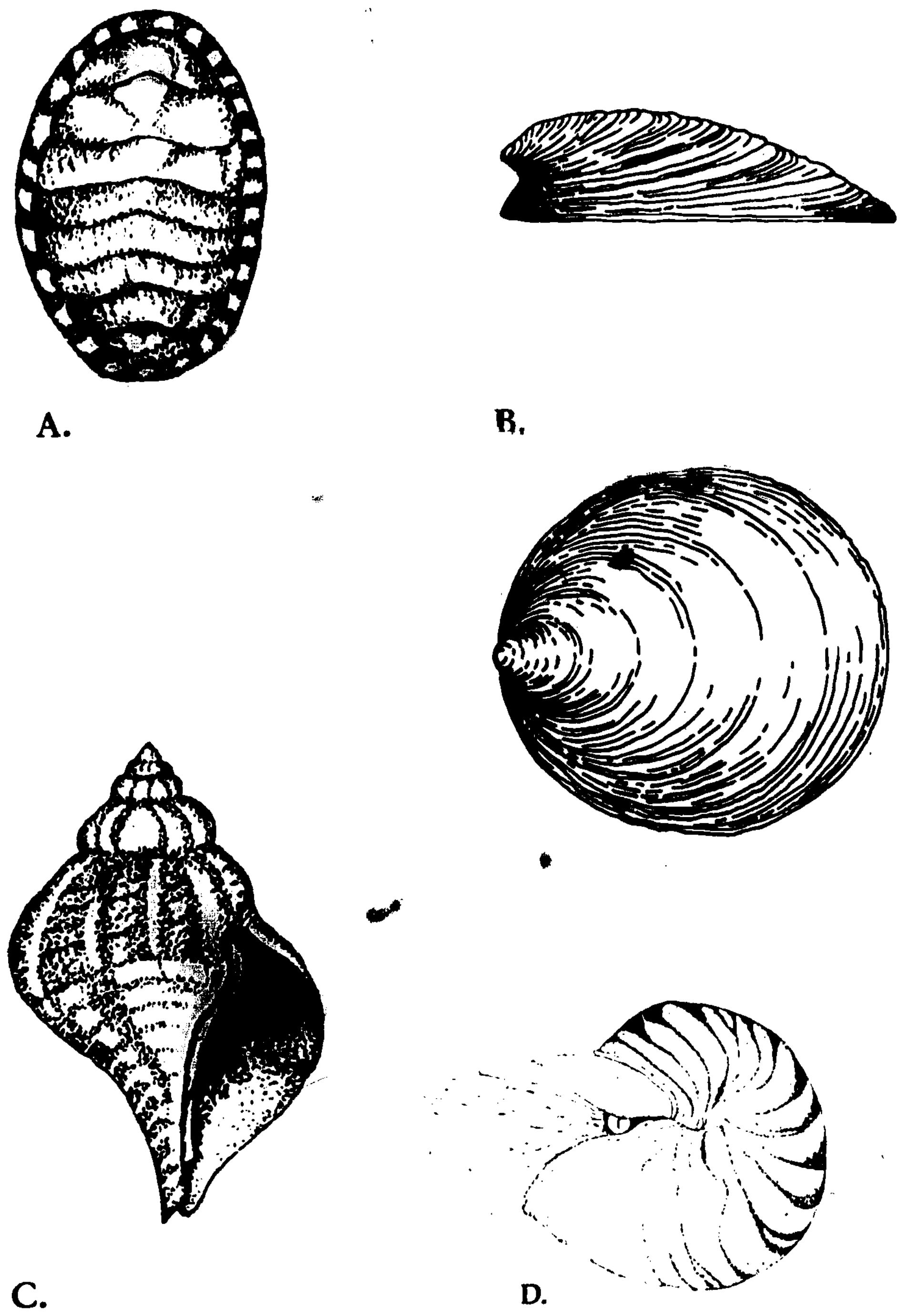


Figure 1. A, Chiton, B, *Neopolina*. C, Oyster drill *(Thais)*. D, *Nautilus*.

mantle cavity which extends around the shell and contains five pairs of gills. The mouth contains a protrusible tongue called the odontophore which bears transverse rows of chitonous material called the radula. The radula is a distinctive feature of mollusks. Modern day chitons have retained this basic body form with an increase in size and musculature of the foot and the number of gills. The shell of a chiton is a series of eight movable plates which facilitates the creeping of the flat, elongated body over uneven surfaces. All other classes of the phylum have deviated considerably from the prototype.

If adaptation to the greatest number of habitats is a sign of success, the most successful body plan is that of the gastropods. The most primitive gastropods retain a rock-clinging way of life while the most advanced display a freedom of movement associated with the loss of the shell, the visceral hump, and the mantle cavity.

Mollusks have adapted to life in an extraordinary number of ecological niches partly because of their ability to evolve a variety of feeding mechanisms. The vast majority are equipped with an apparatus which permits them to take in small particles. The first mollusks most likely had head appendages to gather food and used the radula to rake food into the mouth. Later the head appendages were lost and the radula was used to scrape food from rocks and plants. Primitive bivalves have lost the radula and rely totally on the head appendages. Most of the others have evolved a mechanism for collecting particles in suspension, using currents drawn across the gills.

In certain gastropods a long proboscis has developed for reaching food which would not otherwise be available. The food may be animal tissue, either living or dead. Locally the *Thais*, or oyster drill, bores a hole through the shell of another mollusk and gains access to the soft parts by means of the proboscis (Figure 1C). Some whelks are carrion-feeders and use the proboscis to feed on putrified flesh some distance away. The most highly evolved gastropods are hunters and inactivate their prey by means of fluid injected from the mouth or through a hollow radular tooth.

The most active predators are the cephalopods—squids, octopuses, and cuttle fish. They produce a powerful, poisonous saliva which aids in breaking down the flesh of their prey fo-‑ -asier digestion.

The sory equipment of mollusks includes eyes, tentacles, and osphradia. There are also statocysts and numerous local sense organs in various parts of the body such as the oral lips, the side of the head and the mantle edge. The general surface of the body is sensitive to contact and chemical stimulation. In gastropods the eyes do little more than detect light and, in some cases, the general form of objects. In cephalopods the eye is the dominant sense organ fully comparable to the mammalian eye. With the exception of the *Nautilus*, each eye has a cornea, iris, movable lens, and retina (Figure 1D). Experiments prove that these eyes can detect images, shapes, and some colors. The tentacles are the main tactile organ of gastropods and guide their movements through their environment. In cephalopods suction discs on the tentacles are used to seize the prey in a firm grip to ensure that the prey does not escape. Octopuses use their tentacles to explore small crevices and holes, quickly learning the hiding places of the animals they relish. Paired statocysts are the organs of balance and correspond to the labyrinth in the vertebrate ear. They are also sensitive to sound, but only at low frequencies.

Brain development in the invertebrates is greatest in the cephalopods. The ganglia are fused to form a large brain mass surrounding the esophagus. The larger nerve cells control the motor functions while the smaller ones are aggregated into lobes which serve in sensory integration and memory retention. The giant **axons** of the squid have provided much of the information on which the generally accepted theory of nerve conduction rests.

In the majority of mollusks the sexes are separate and even in **hermaphroditic** forms cross fertilization is the rule. In chitons and bivalves the ova and the sperm are liberated into the water and fertilization is external. Eggs either float singly, are incubated in the mantle cavity, or are attached in a mass to the substrate. Higher gastropods and cephalopods have more elaborate egg coverings and fertilization is internal. In some gastropods and in all cephalopods, development of the organism takes place inside the egg case and the young hatch as miniatures of the adults. In all others the embryo hatches as a trochophore larva.

VOCABULARY

Annelid—a segmented worm.
Axon—a nerve process that carries an impulse away from the nerve body.
Bilateral symmetry—body pattern in which one side of an animal is a mirror image of the other.
Bivalve—a mollusk possessing a shell of two valves hinged together; includes clams, oysters, and mussels.
Carrion—dead and decaying flesh.
Cilia—tiny, hairlike projections; used for locomotion in some organisms.
Dorsal—the topside of an organism.
Hermaphroditic—referring to the condition in which an organism has both male and female reproductive systems.
Hypobrachial gland—a gland which produces a secretion that consolidates any sediments drawn into the mantle cavity.
Invertebrate—an animal without a backbone.

Activity: Behavior of Certain Gastropods

Objectives

To make "radula tracks" of *Littorina* or various freshwater snails.
To study the parts of the **oyster drill** and to observe its feeding behavior.

Materials

Part I: *Littorina* and various freshwater snails, 3 inch square glass plates, bottles of India ink, small paint brushes, glass or plastic containers large enough to hold a glass plate, varnish (optional)
Part II: oyster drills, oysters, chopped oyster, two complete salt water aquaria set-ups, thread

Procedure

1. The **radula** is important to both **herbivorous** and **carnivorous** snails since it is used for obtaining food. This structure functions in a rasping fashion, that is, it dislodges food

material along the surface of rocks or other materials by means of a scraping process. The food material collected in this manner is directed into the mouth of the snail. The radula is sometimes difficult to see in a living snail; however, we can observe the results of the action of the radula through preparation of "radula tracks". Obtain a piece of glass, a bottle of India ink, and a small paint brush from the supply table. Paint the piece of glass with India ink and allow it to dry thoroughly. Next, place the piece of glass in a container of sea water or fresh water, depending upon the type of snail you are using. Place one or more snails on the painted glass plate. Make observations for the next 5–10 minutes or longer but do not disturb the snails unless they move off the glass plate. Describe what happens and then make a drawing of what you see.

Working with your partner and using the observations that you recorded, describe what the radula must look like within the actual living snail.____________________

____

If you were to use a different snail in your experiment, what would the new radula tracks look like? Would they look the same as the previous set?____________________
Upon what facts, observations, or other data do you base this conclusion?____________________

____

You may preserve your radula tracks by removing the glass plate from the water, allowing it to air dry, and applying varnish to the glass.
II. Place two oysters and two oyster drills in one salt water aquarium. Allow the oyster drills to drill through the shells. This may take several days. Describe the day-to-day behavior of the oyster drill.____________________

____

Put the other two oyster drills in the second aquarium and drop two or three small pieces of chopped oyster on the bottom of the aquarium. How long does it take the oyster drill to find the chopped oyster? ____________________ What "senses" do you think might be used by a snail when trying to locate food material?____________________

____

After several hours, hang two small pieces of chopped oyster by a thread five to seven centimeters in the water. Observe the oyster drill's foot as the organism moves up the glass. Observations.____________________

____

Notice the action of the radula as the oyster drill eats. How would you describe its motion?____________________

____

Place small pieces of oyster on the top edge of the aquarium and observe the snail as it eats. How is the proboscis useful in gathering food?____________________

____

VOCABULARY

Carnivorous—refers to animals which prey on other animals.
Herbivorous—refers to animals that are adapted to feeding on plants.
Oyster drill—a shelled mollusk which obtains its food by drilling a hole in an oyster shell and digesting the oyster.

Proboscis—a tubular extension used in feeding.
Radula—a rasping organ used in feeding and found in gastropod mollusks.

Activity: **What Can a Shell Tell Us?**

As you walk along the beach, shells of various sizes, shapes, and colors are nearly always plentiful. Many visitors to the Gulf Coast pick up shells along the beach. Unfortunately, these shells are sometimes collected, put in a box, placed somewhere on a shelf in the back of a closet, and never looked at again. Today we shall observe some shells and try to develop an understanding of the organism that once lived inside.

Objectives

To examine the similarities and differences in some common shells that we might find along the **strand line.**
To become aware of anatomical features of some of the common mollusks.
To identify some common mollusks by using a **taxonomic key.**
To prepare a simple key to enable others to identify an unknown mollusk.

Materials (per group of three to four students)

Set of locally collected shells, e.g., mussel, razor clam, scallop, whelk, and boat shells or Atlantic Coast Shell Collection (available from Carolina Biological Supply Company)

Procedure
Part I

Several shells have been selected for your study today. Take them out of the container and examine each shell carefully. Separate your assortment of shells into two groups, and list the characteristics of each group.

Group I	Group II
______	______
______	______
______	______

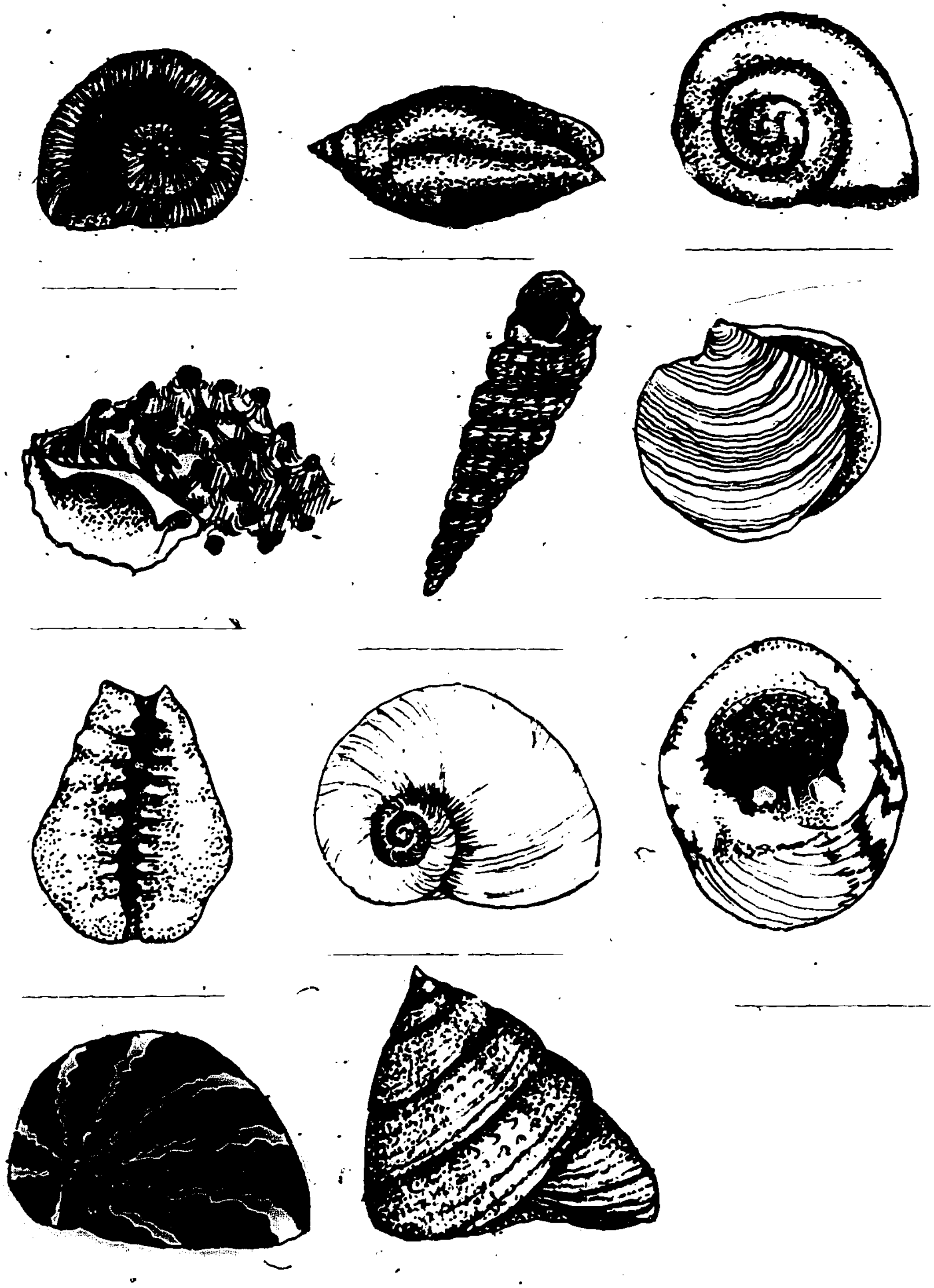
Now make several groups from each of the two previous groupings. List the attributes that caused you to divide them in this manner.

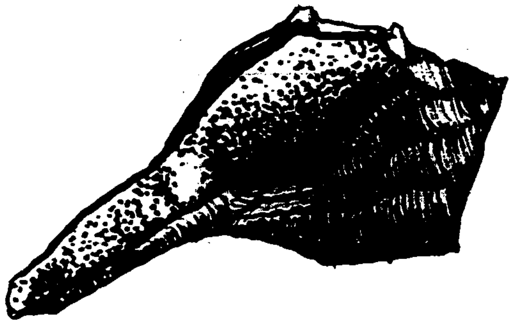
______	______	______	______
______	______	______	______
______	______	______	______

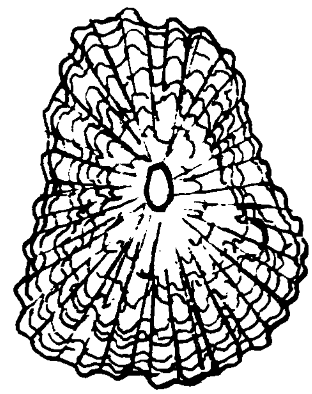
Could we continue separating the groups until there is only a single member in each group?______

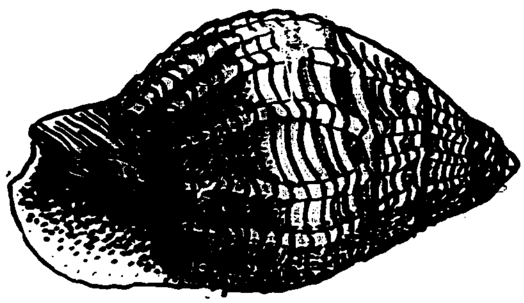
Part II

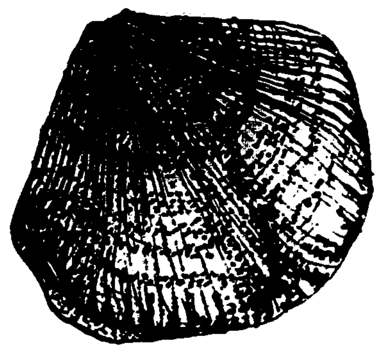
The following two pages contain sketches of some of the shells from your collection. The first thing you should do is to match as many of the shells with the sketches as you can. You will note that different structures are shown in each shell. This will cause you to observe the shells for differences and similarities.











Numbered Shells

In Part I you divided your collection of shells into two groups. List below the numbers of the shells that you included in each of your two groups.

Group I	Group II
______________________	______________________

Part III

Prepare a word key for the collection of shells that has been provided for you. Remember that each set of two statements, called a couplet, should be relevant to each shell. You should be able to say "yes it is" or "no it is not" in each case. The observations that you make during the other activities should be of value to you. There are also additional pages of example univalves (Figure 1) and bivalves (Figure 2) which will help you with unfamiliar terms. Typical gastropod shells with the parts labeled can be found in Figure 3.

VOCABULARY

Bivalve—a mollusk possessing a shell of two valves hinged together; includes clams, oysters, and mussels.
Strand line—a shore or beach; especially, one above the present water level.
Taxonomic key—a table in which the distinguishing characteristics of a group of plants or animals are arranged so as to make it easier to determine their names.
Univalve—a mollusk that possesses only one valve (shell).

Key to the Shell Collection

1. (a) ______________________________
   (b) ______________________________
2. (a) ______________________________
   (b) ______________________________
3. (a) ______________________________
   (b) ______________________________
4. (a) ______________________________
   (b) ______________________________
5. (a) ______________________________
   (b) ______________________________
6. (a) ______________________________
   (b) ______________________________

7. (a) ____________________
(b) ____________________
8. (a) ____________________
(b) ____________________
9. (a) ____________________
(b) ____________________
10. (a) ____________________
(b) ____________________
11. (a) ____________________
(b) ____________________
12. (a) ____________________
(b) ____________________
13. (a) ____________________
(b) ____________________
14. (a) ____________________
(b) ____________________
15. (a) ____________________
(b) ____________________
16. (a) ____________________
(b) ____________________
17. (a) ____________________
(b) ____________________
18. (a) ____________________
(b) ____________________
19. (a) ____________________
(b) ____________________
20. (a) ____________________
(b) ____________________
21. (a) ____________________
(b) ____________________
22. (a) ____________________
(b) ____________________
23. (a) ____________________
(b) ____________________
24. (a) ____________________
(b) ____________________
25. (a) ____________________
(b) ____________________
26. (a) ____________________
(b) ____________________
27. (a) ____________________
(b) ____________________
28. (a) ____________________
(b) ____________________

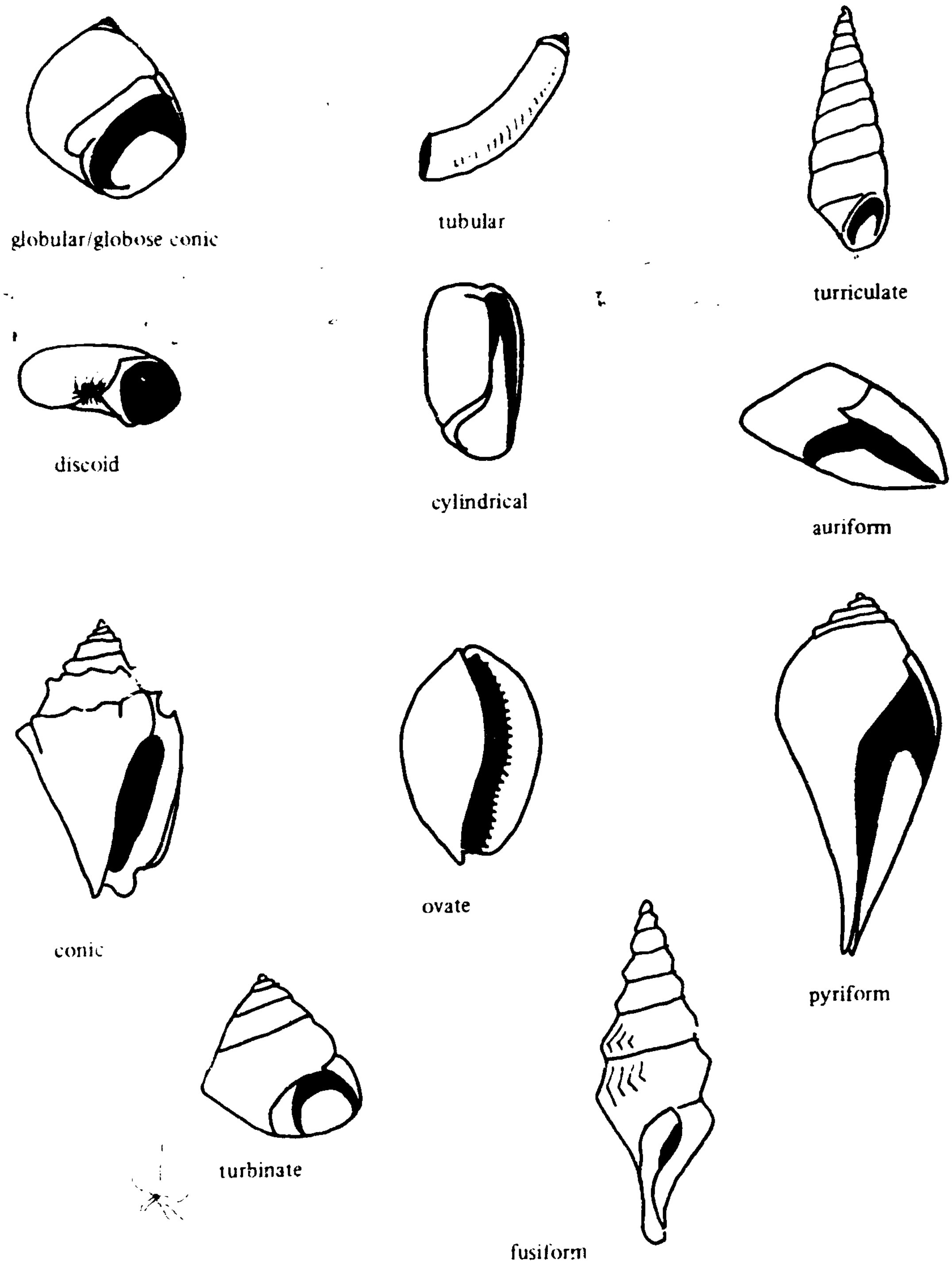


Figure 1. Diagrammatic illustrations of typical gastropod shapes.

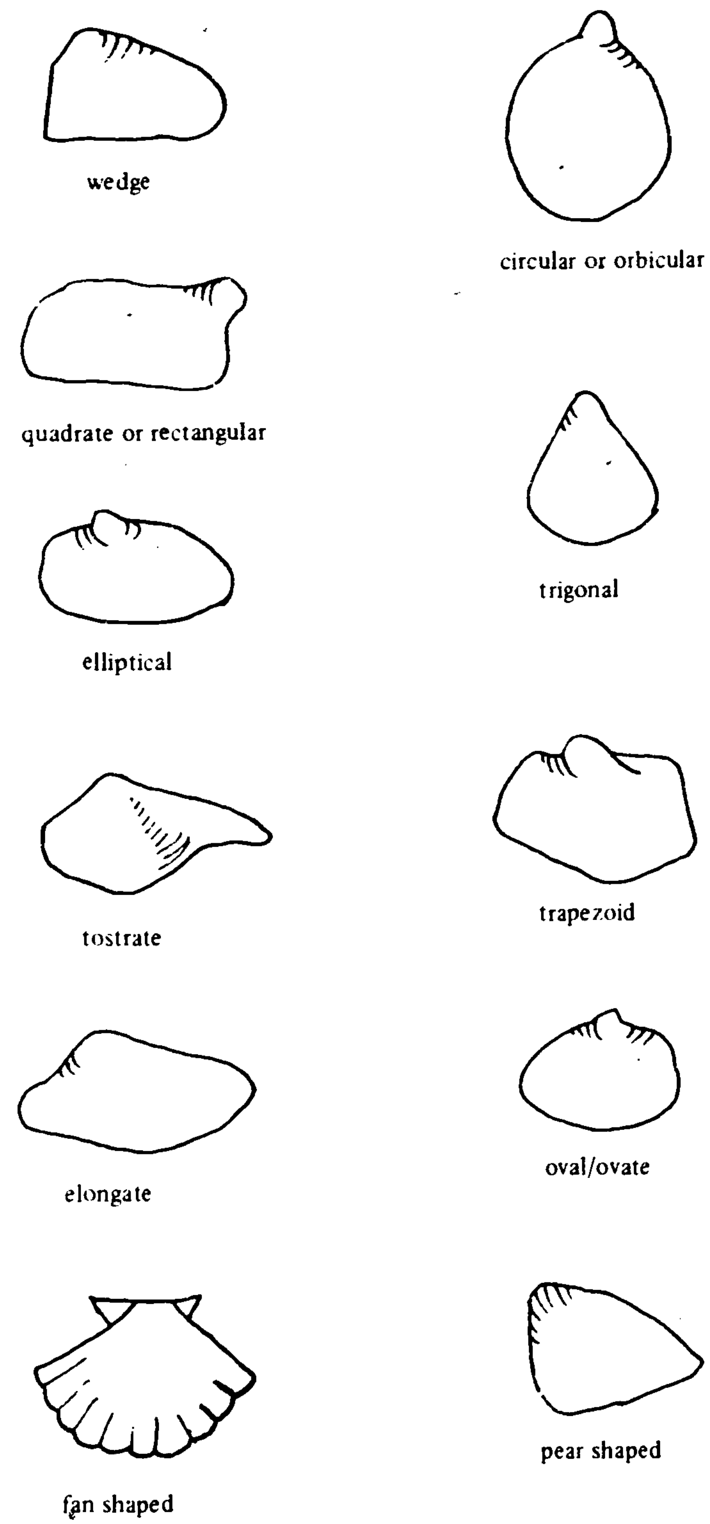


Figure 2. Diagrammatic illustrations of typical bivalve shapes.

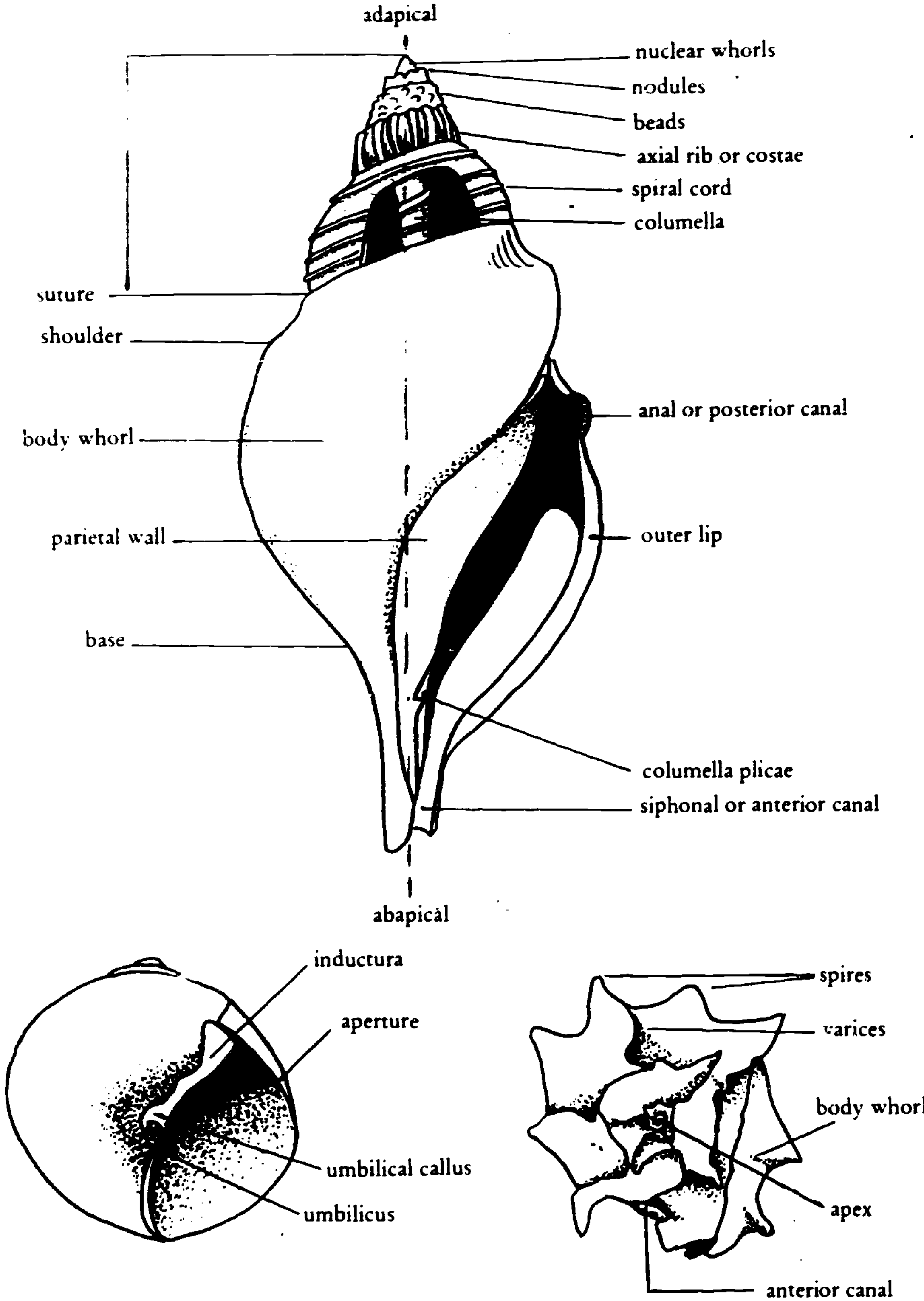


Figure 3. Parts of the gastropod shell. In this composite shell the columella is seen through a cutaway section.

Activity: **Are All Members of a Species Alike?**

Objective

To perform investigations that will demonstrate size, color, and weight variations within a species.

population is made up of many organisms of the same species living in a particular geographical area. The individuals usually spend their entire **life cycle** in one **community.** They begin their life cycles, grow to maturity, go through a declining period and finally die This individual growth curve is very similar to the growth curve for the entire population. There will be a very rapid growth period in the entire population. This is followed by a leveling off or steady state if the environment can support a large number of individual organisms. If the environment cannot support the population then it will have a tendency to decline. Usually in any community the number of organisms entering a population is equal to those that are leaving.

When we examine a population we will find organisms at all stages in the life cycle. Color, size, and age will be somewhat different among the organisms of a selected **random sample.** Many times these differences will cause organisms to appear to be from different populations when they are not. Adult organisms may not be of the same uniformity due to variation that exists within a species. Why do you think we have variation?____________

____

In this investigation we will attempt to discover if there is variation in the common marine organisms that are found along the coastline of Mississippi and Alabama. We will use the small coquina clam, *Donax variabilis*, in our investigation.

Materials (per group of students)

25 *Donax variabilis* shells, sheet of graph paper marked off in 0.3 cm squares, balance

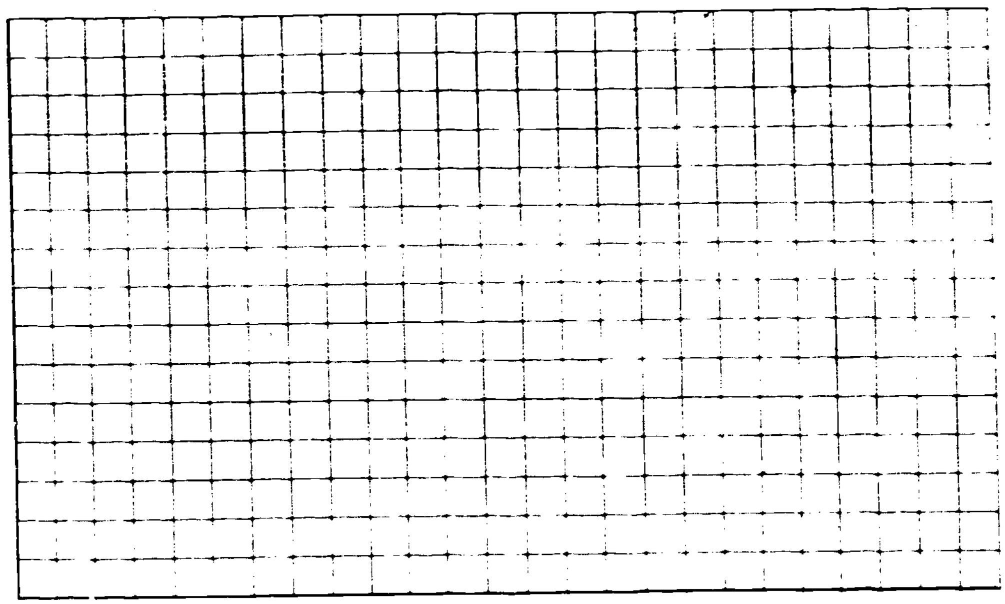
Procedure

Select 25 *Donax* shells at random from the storage container. Place a shell on the graph paper and determine how much space it occupies. To determine this amount of space draw around the shell with your pencil, remove the shell from the paper, and count the number of 0.3 cm squares that were covered by the shell. For those squares that were partially used, estimate the amount of area that was covered by the shell. Repeat this procedure for the remaining 24 shells. Record the number of squares covered by each shell in the appropriate spaces on the data sheet.

Weigh each shell to the nearest tenth of a gram and record the weight on the data sheet. Determine the color of each shell as best you can and record in the proper space on the data sheet. Compile all your data and prepare a line graph. (Note that graph paper has been provided and that the axes have already been labeled.)

Distribution of shell size

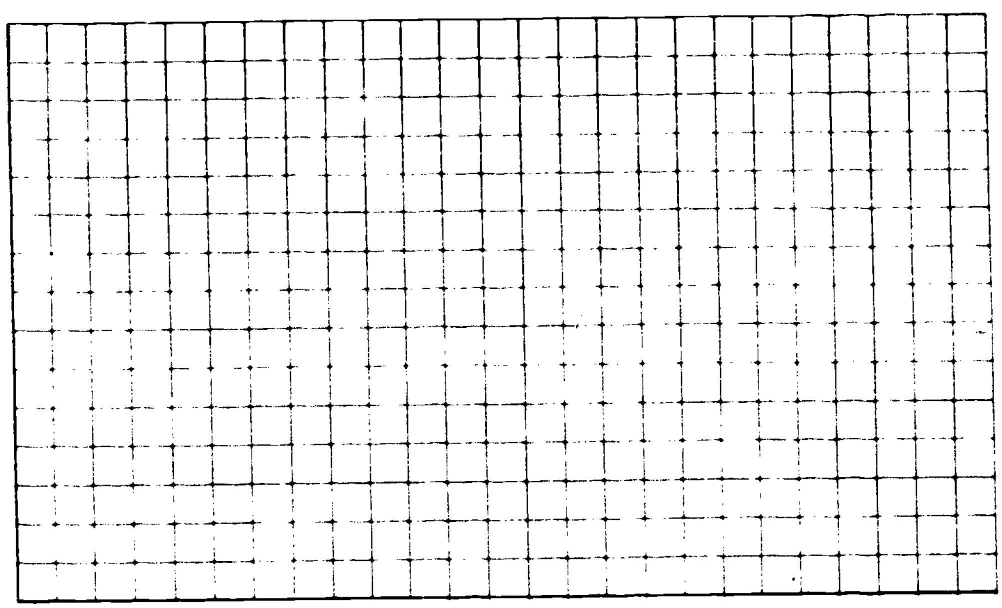
Number of Shell



Number of 0.3 cm squares covered by a shell

Distribution of shell weight

Number of Shell



Weight in grams

Data Sheet for *Donax variabilis*

Shell No.	Number of Squares Covered	Mass of Shell	Predominant Color of Shell

Extending Your Thoughts

1. What is the most accurate number of squares that can be covered by the small clam *Donax*?
2. What is the most accurate weight of a typical *Donax* shell?
3. What is the color most frequently encountered in your set of shells?
4. How did you arrive at the answers to the above three questions?
5. How does your graph on shell size compare with the graphs constructed by your classmates?
6. Would a larger number of individuals from a population increase your estimate of that population?
   Explain
7. Does there appear to be any relationship between color and weight?
   Explain

   Does there appear to be any relationship between size and weight?
   Explain
8. Should you find a population of *Donax variabilis* in an isolated area 400 miles from where you collected your sample, what would you expect as far as color, size, and weight of the newly discovered shells?
9. How would you verify that the clams found in question eight are the species that we thought they were?
10. Do you think we would find variation in such organisms as the squid, octopus or oyster just as we found in *Donax*? Explain

VOCABULARY

Community—all of the populations of organisms in a particular area.
Life cycle—a fairly definite period of life.
Population—a group of individuals of any one kind of organism in a given ecosystem.
Random sample—a type of sample in which each individual in the group being studied has an equal chance of being selected.

Activity: A Common Cephalopod—The Squid

Objectives

To examine the external and internal structures of a representative cephalopod.
To become familiar with the life history of the squid.

The squid is a common inhabitant of the eastern seaboard and the Gulf of Mexico. These animals may range in size from 2.5 cm to the giant squid which may be 6 meters in length or longer. Fossil records indicate that the squid has been around for a long time.

The characteristic shape of the body enables the squid to dart through the water with great speed. This lightning-like speed is accomplished by **jet propulsion.** Water within the mantle cavity is forcibly ejected through the siphon which propels the squid in the opposite direction. For ordinary swimming the squid uses its **lateral** muscular fins which permit backward and forward movement at slow speeds.

Even though the squid is a fast swimmer, it often falls prey to some of the larger predators. If the squid becomes cornered, it has the ability to discharge an inky fluid into the siphon and thus out of the body. This mechanism usually clouds the water and enables the organism to swim away from the attacker.

Squids have the ability to change color, which is also a very effective protective mechanism. Complex **chromatophores** lying below the thin epidermis are controlled by tiny muscles.

Two kinds of skeletons are found internally in the squid. One is called a **pen.** It is composed of chitin and lies in the mantle. The other one is composed of cartilage and is similar in structure to a skull that encloses the brain.

The foot of the squid is composed of ten muscular arms that possess suction disks. Their arms may be modified for different functions. One pair is longer than the others and is used in capturing prey. The other arms may assist in food-getting by holding the prey while it is being torn apart by the radula and crushed by the **mandibles.** The lowest left arm in male squid is modified for sperm transfer.

The internal organs are much like those of other mollusks. The digestive system contains a rather long esophagus, opening into a blind stomach. There is a large caecum extending from the stomach to the posterior portion of the organism. The stomach empties into an intestine which opens through the anus into the mantle cavity. This provides the same flushing system that is used by the **bivalves.**

Circulation is accomplished by two types of pumping structures. One type, an arterial heart, pumps arterial blood throughout the body. The other type consists of two branchial hearts, one located at the base of each gill. They receive the venous blood from the body and pump it through the gills to the arterial heart.

The nervous system consists of a **ganglion,** referred to as the brain, that encircles the esophagus. Huge nerve fibers that radiate from this central ganglion innervate the muscle fibers for contraction.

As is found within many other invertebrates, the squid has a pair of **statocysts** located in the skull that act as organs of equilibrium. Light **stimuli** are received by an eye that resembles the eye found in vertebrates. The eye is made up of a transparent cornea, a pigmented iris, a somewhat spherical lens located in a vitreous chamber, and a retina.

When the squid matures sexually, a single gonad fills the posterior end of the organism. The mature male produces packets of sperm cells called **spermatophores.** The male transfers these packets of sperm to the female and she fertilizes the eggs. The eggs are embedded in a jelly-like substance. Fertilization is accomplished and the fertilized eggs develop into tiny individuals that resemble the parent. They swim about in the water feeding on plankton. It is not uncommon to see rather large schools of tiny squid.

You will now examine a preserved specimen of the squid *Loligo*. Try to locate each anatomical feature as it is discussed. (Figure 1 should help you do this.) Locate the mantle which covers most of the body. Note that it is thick and muscular and takes the place of the shell found in other mollusks for protection of the internal organs. The skin is of a mottled color where the dark color is due to irregularly-shaped pigment cells called chromatophores. Remove a section of skin and place it on a slide and view the difference in color and the irregular nature of the chromatophore.

Water enters the mantle cavity of the living squid around the head. The water within the mantle cavity is expelled in a jet-like fashion through the funnel (excurrent siphon). This funnel can be directed either forward or backward. This provides the squid with great versatility in locomotion. Can you find this funnel? Now locate the eyes. Structurally they are very similar to ours. Can you name some similarities? ____________________

____

The foot of this animal is not like those of the bivalves. How is this foot constructed? ____

____

There are ________ arms found on the specimen. Suckers are found on ________ of the arms. Two arms are longer. What is the function of these long arms which are sometimes called tentacles? ____________________

Locate the mouth at the center of the ring of arms and tentacles. Describe what you see. ____________________

____

It is surrounded by a structure called a buccal membrane with several sucker-like projections on it. If the organism is a female, there will be a small pouch called the sperm receptacle found on the buccal membrane. Can you now determine the sex of the squid? ____________ What is it? ____________________

You have already learned that the male squid produces sperm in packets called spermatophores. During mating the packets of sperm are transferred from the male squid to the sperm receptacle of the female by a modified arm called the **hectocotylus.** The female will then use the sperm to fertilize the eggs as they are produced. Eggs are produced in masses with each mass containing around one hundred eggs. The egg masses are attached to the shallow bottom and left to develop without parental care.

To expose the beak make a cut between the two ventral arms. As you do this you will expose the buccal bulb. Then carefully remove the attached membranes to expose the hard beak or mandible. What do you think the function of the beak is?

____

The buccal bulb contains two pairs of salivary glands that open into the mouth cavity. One pair of salivary glands secretes salivary enzymes and mucus for digestion; the other pair produces venom that enters the prey through bites inflicted by the beak. The buccal bulb also contains a tongue-like radula. Remove a section of this and examine it under the

microscope. Describe what you see?____
____ How does it function?
____

In the space below draw a sketch of the external view of your squid. Label as many parts as you can.

Now examine the sketch of the internal organs of the squid and try to answer the following questions.

Locate the parts of the digestive system. Name each part in order beginning with the mouth and give the function of each organ.

mouth ______________ ______________
______________ ______________
______________ ______________
______________ ______________
______________ ______________
______________ ______________

Can you find the ink sac? What is the function of this structure? ______________
____
____

What is the pen? ______________
____

VOCABULARY

Bivalves—a mollusk possessing a shell of two valves hinged together.
Chromatophores—special pigment cells that are responsible for color changes of cephalopods.
Ganglion—a mass of nerve cells.
Hectocotylus—transformed arm that serves as a male copulatory organ in cephalopods.
Jet propulsion—propulsion in one direction by a jet of water that is forced in the opposite direction.
Lateral—toward the side.
Mandibles—a strong, cutting mouthpart.
Pen—a feather-shaped plate just beneath the skin of the back or anterior wall of the squid.
Spermatophores—sperm packets.
Statocysts—balancing organs.
Stimuli—anything that evokes a response from an organism.

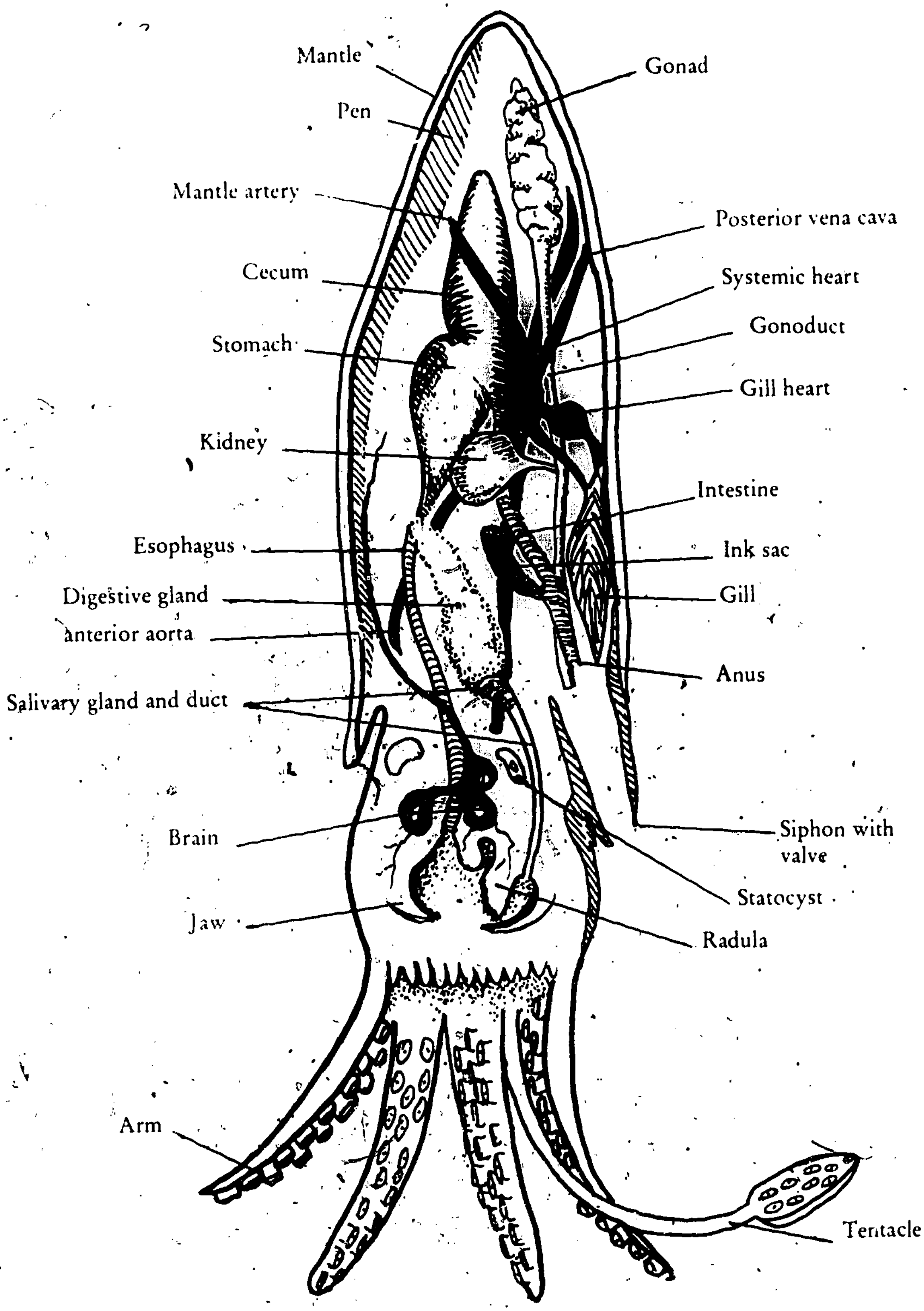


Figure 1. Lateral View of Squid Anatomy.

CONCEPT G

The echinoderms are a group of marine organisms that have radially symmetrical bodies. They are unique in their development and in their use of tube feet for obtaining food and for locomotion.

Objectives

Upon completion of this concept, the student should be able:

a. To list four members of the phylum Echinodermata.
b. To describe the method of feeding used by sea stars.
c. To explain the role of the madreporite in the water vascular system of the starfish and sea urchin.
d. To discuss the method by which sea urchins protect themselves.
e. To describe the sea urchin's role in the marine community.
f. To explain the method of locomotion used by sand dollars.
g. To list two methods used by sea cucumbers in protecting themselves.

THE ECHINODERMS (PHYLUM ECHINODERMATA)

Phylum Echinodermata is exclusively marine. It is divided into five classes: Asteroidea (starfish), Ophiuroidea (brittle stars), Echinoidea (sea urchins and sand dollars), Crinoidea (sea lilies, feather stars), Holothuroidea (sea cucumbers). Each member of this phylum has five divisions to the body and is **radially symmetrical.** Most all have movable **spines.** Tube feet are present in all these organisms, but all of them do not have suction cups. Echinoderms are the only creatures in the world that have tube feet manipulated by a water vascular system. Interestingly enough, among the nearly 5000 species of echinoderms not one lives in fresh water or on land.

The earliest echinoderms were the crinoids, or sea lilies (Figure 1). These stalked forms were attached to the floor of the oceans. Some 2100 fossil species of crinoids are known, in contrast to about 900 living species. These are not found in Mississippi or Alabama coastal waters and therefore will not be included in this discussion. We shall discuss organisms included in three of the four remaining classes: starfish (Asteroidea), sea urchins and sand dollars (Echinoidea), and sea cucumbers (Holothuroidea).

The Sea Star

The echinoderm most familiar to everyone, even to those who have never been to the seashore, is the starfish (Figure 2). It is more correctly called the sea star because it bears no resemblance to a real fish; however, the name "starfish" has gained wide usage and is hard to change.

The sea star has a spiny skin. The spines are attached to loosely hinged **calcareous** plates. The flexibility of these plates can be compared to the flexibility of an expandable watch band. The common sea star, which is found in **tidal pools** at low tide, has a warty outer covering. Even though the sea star has a skeleton, the skeleton does not permit the freedom of movement that **vertebrates** enjoy. Since the sea star cannot move rapidly, this does not pose a problem.

The sea star is one of the most greedy of **predators** on the ocean floor. They feed mainly on clams and oysters. When a sea star chooses to eat a clam or oyster it surrounds the two shells with its mouth oriented over the opening between the two shells, attaches its tube feet to the two shells, and begins to pull (Figure 3). As the shells separate, the sea star turns the lower part of its stomach inside out and extends it through the mouth, enveloping the soft parts of the shellfish and digesting them.

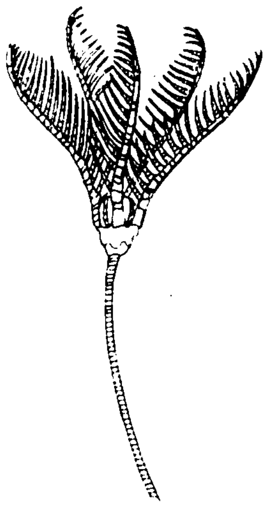


Figure 1. Sea Lily.

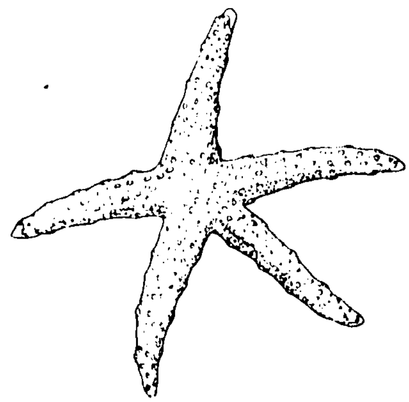


Figure 2. Sea Star (Starfish).

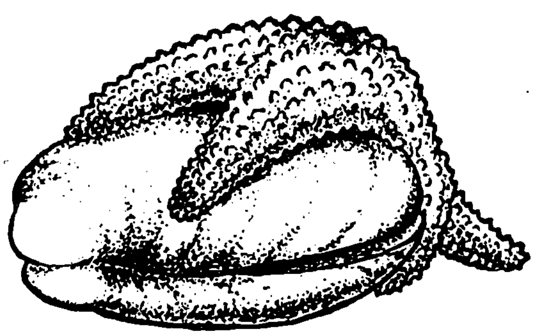


Figure 3. Starfish Opening a Clam.

One of the most remarkable systems in echinoderms is the water vascular system. Running lengthwise along the oral surface of each arm of the sea star is a groove. Located in these grooves are four rows of tube feet which expand and contract. These tube feet are extensions of the radial canal which runs down the length of each arm. The radial canals stem from a ring canal in the center of the animal. Another canal, the stone canal, branches off the ring canal and ends at the aboral surface by means of disc-shaped sieve-plate called the madreporite. The madreporite (sieve plate) is the opening through which water is drawn (Figure 4). It is used to fill the hydraulic system that allows the sea star to operate its suction cup feet and attach itself to the sea floor so it can move. The tube feet can be lengthened or contracted by changes of water pressure (Figure 5).

The sea star is of no commercial value. Its contribution to the marine environment lies in the fact that its feeding habits involve cleaning up the ocean bottom and much of the dead organic material of tidal pools.

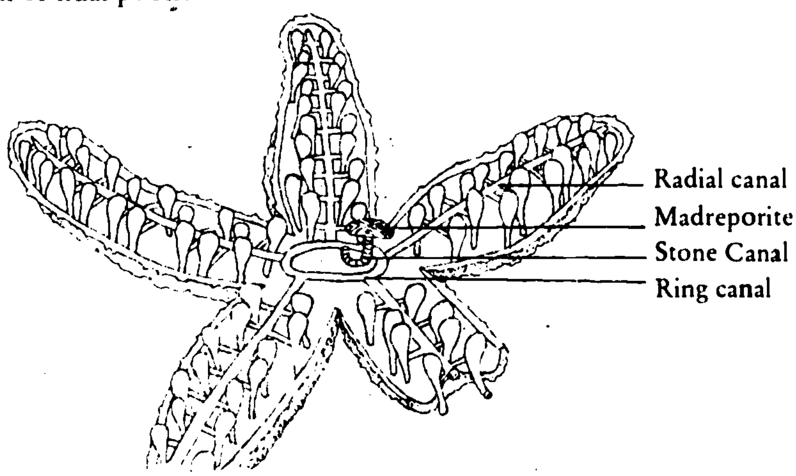


Figure 4. Water Vascular System.

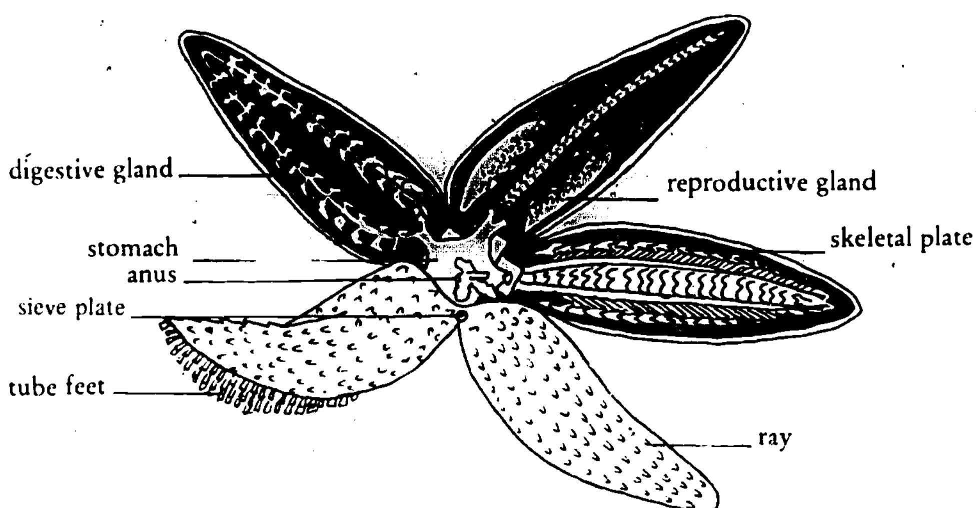


Figure 5. Internal Structure of Sea Star.

The Sea Urchin

Sea urchins seem very unlike sea stars; yet they have the same basic structure (Figure 6A). All echinoderms have mineral skeletal plates, but the skeleton of the sea urchin is most pronounced because it forms a stiff protection for the body. It also has a spiny covering which gives the organism an untidy appearance. This covering of locked plates forms a rigid capsule called a test. When a sea urchin dies and the spines have fallen off, the star design is easily seen in the remaining test. This star design is formed by the location of five double rows through which the tube feet protrude.

The general shape of a sea urchin's body is globular and flattened on the ventral side. Since this animal does not appear to have any way of determining direction, it wanders rather aimlessly with its mouth pressed tightly to the ocean or tide pool floor. Like the sea star, it is equipped with a madreporite on the aboral surface (Figure 6B). Water is drawn in through this opening for the operation of the tube feet. The feet are more slender and longer than those of the sea star. They are arranged into five double rows.

The spines of the sea urchin are used for locomotion and protection from predators. These spines have the ability to turn about because each one is loosely attached to a single plate. If the test of a sea urchin was touched with a stick, the spines would all turn in the direction from which the urchin was touched. Along with tube feet, the spines also help to push the animal along the ocean floor. In the event that the animal is turned onto its back, it is able to upright itself by using the spines as small levers.

In the center of the oral surface of the shell is an opening for the mouth. This structure is composed of five jaw pieces primarily designed for scraping algae or any dead animal material from the ocean floor (Figure 6C). The sea urchin uses its five teeth to chew its

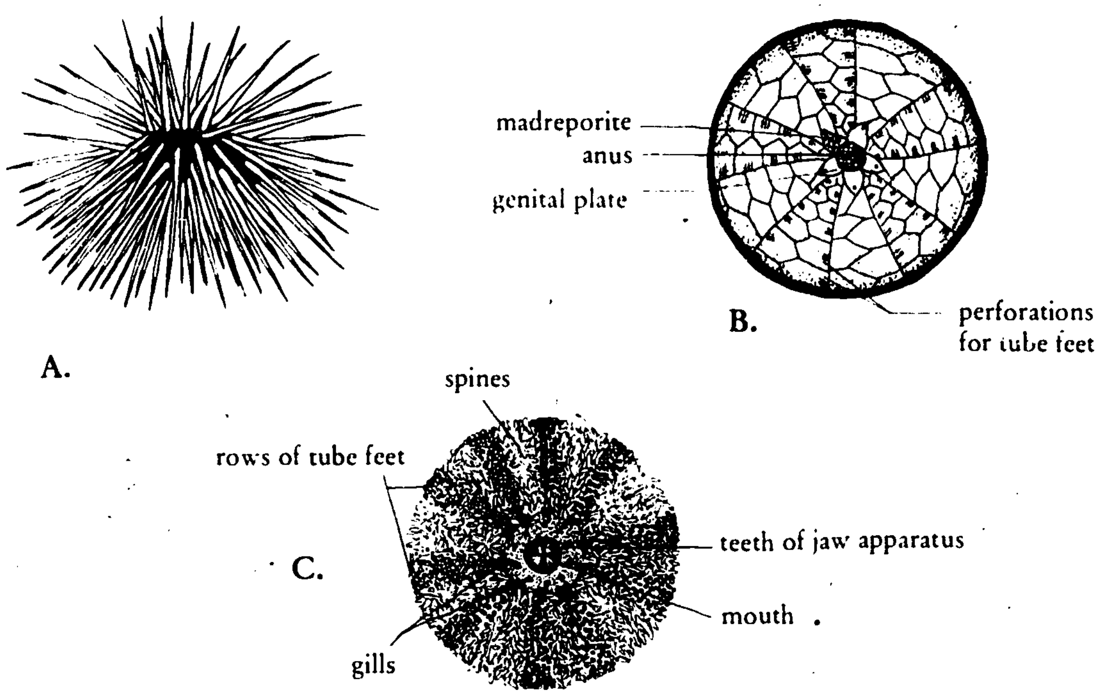


Figure 6. Sea Urchin. A, Entire organism. B, Aboral surface. C, Oral surface.

food. The digestive tract is longer than that of the sea star because the urchins feed upon vegetation and animal waste that require a longer digestive time. The stomach cannot be turned inside out. The anus is functional and is located to one side of the madreporite (Figure 6B). Although other invertebrates have biting jaws, the urchins possess grinding or chewing organs.

The sea urchin's greatest contribution to the marine community stems from its feeding habits, which involve cleaning up the dead material that settles to the bottom of tide pools.

The Sand Dollar

Sand dollars belong to the same class as sea urchins but, unlike sea urchins, they are flattened and covered with very short spines (Figure 7). The sand dollar is one of the least noticeable of the echinoderms because it is not generally found in tide pool areas. It is more characteristically found beneath the surface of the sandy bottom of the ocean.

The sand dollar has many more spines than either the sea star or sea urchin. This is generally not evident because dead sand dollars that are found on the beach have lost their spines. The spines are small and generally not noticed.

The sand dollar has a different shape from the others in this phylum. The oral surface is very flat and the aboral surface is only slightly rounded. The mouth of this animal is located in the center of the oral surface. The sand dollar feeds on materials found on the bottom of the ocean.

The skeleton of the sand dollar is not flexible. Consequently, sand dollars move by using their spines and small tube feet on both surfaces of their body. The plates which make up the test of the sand dollar are fused as they are in the sea urchin. A close look at the sand dollar will easily show the five branches of the starred pattern which is common to the echinoderms (Figure 7).

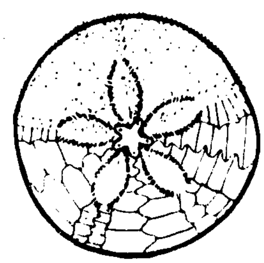


Figure 7. Sand Dollar.

The Sea Cucumber

Because of its appearance, the sea cucumber does not seem to fit into the echinoderm group at all. However, the organism definitely has radial symmetry. Unlike other echinoderms, sea cucumbers have a leathery skin and a slimy feel. Tube feet are found on their ventral surface. The dorsal surface has two rows of tube feet that are not as well developed. Breathing is accomplished by the upper tube feet and traveling is accomplished by movement of tube feet beneath the animal (Figure 8).

The soft texture of the sea cucumber's body also sets this organism apart from the other members of this phylum. The skeleton of other echinoderms is hard while that of the sea cucumber is internal and made of small scattered bones called ossicles. It is this adaptation that allows the sea cucumber to bend, contract, and stretch out.

When feeding, the cucumber uses from ten to thirty **tentacles** located at one end of its body. The tentacles are extended and used to trap **plankton.** They are then placed into the mouth, cleaned, and pushed back out to catch more food. When the animal is startled, all the tentacles can be pulled into the body for protection. Another interesting phenomenon can occur when the sea cucumber is startled, annoyed, or attacked. The cucumber can eject its internal organs to distract the attacker. This organism is capable of replacing lost organs by regeneration.

Most sea cucumbers earn their keep in the world by removing decaying organisms or small, living organisms from the tiny spaces between mud and sand particles.

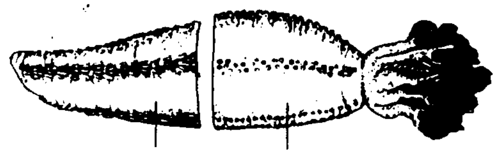


Figure 8. Sea Cucumber.

VOCABULARY

Aboral—refers to the side of the animal which is opposite the mouth.

Adaptation—the process by which a species becomes better suited to survive in an environment.

Calcareous—consisting of calcium carbonate.

Madreporite—the sieve plate on the aboral surface of an echinoderm. Water passes through this opening to operate the water vascular system.

Oral—pertaining to the same side as the mouth.

Ossicle—a little bone or bone-like part.

Plankton—small plants and animals floating in the upper layers of the water column.

Predator—an animal that preys upon another organism.

Radial symmetry—a body plan in which a cut lengthwise through the middle in any direction produces two identical halves.

Spine—a stiff sharp-pointed process found on the surface of an organism.

Tentacle—a long appendage, or "feeler", of certain invertebrates.

Test—the external shell or hard covering of many invertebrates.

Tidal pool—a pool of sea water temporarily isolated in the intertidal region as a result of the tide going out.

Tube feet—the feet of the sea star and sea urchin. Water passes through these hollow cylinders to operate the water vascular system.

Ventral—the underside of an organism.

Vertebrates—animals with backbones.

CONCEPT H

Barnacles, a group of strictly marine crustaceans, are important as fouling organisms.

Objectives

Upon completion of this concept, the student should be able:

a. To give the common name for two kinds of barnacles.
b. To explain why barnacles are economically important.
c. To discuss adaptations made by barnacles in order to live in certain areas.
d. To discuss the reproductive process used by barnacles.

THE BARNACLES (PHYLUM ARTHROPODA, CLASS CRUSTACEA)

The barnacle is one of the most obvious and most numerous animals found along the shores of Mississippi and Alabama. It encrusts intertidal and subtidal pilings, breakwaters, rocks and boulders, living and dead shells, and even animals such as horseshoe crabs.

Barnacles are sometimes thought of as mollusks because their bodies are entirely enclosed within a series of plates made of calcium carbonate. However, the structure of barnacles during their development, together with the possession of paired, jointed appendages, indicates that these organisms are true arthropods belonging to the class Crustacea.

The cirrus-like or feathery feet of some better-known barnacles are the basis for the subclass designation, Cirripedia (Figure 1A). There are several readily distinguishable groups of true barnacles. These include: the stalked forms, to which belong the goose-necked barnacles (Figure 1B); the common rock barnacles often called acorn barnacles (Figure 2); a group which is smaller and asymmetrical when compared with the acorn barnacles; and three groups of barnacles whose plates are composed of chitin. (These three groups are parasites of different invertebrate hosts.)

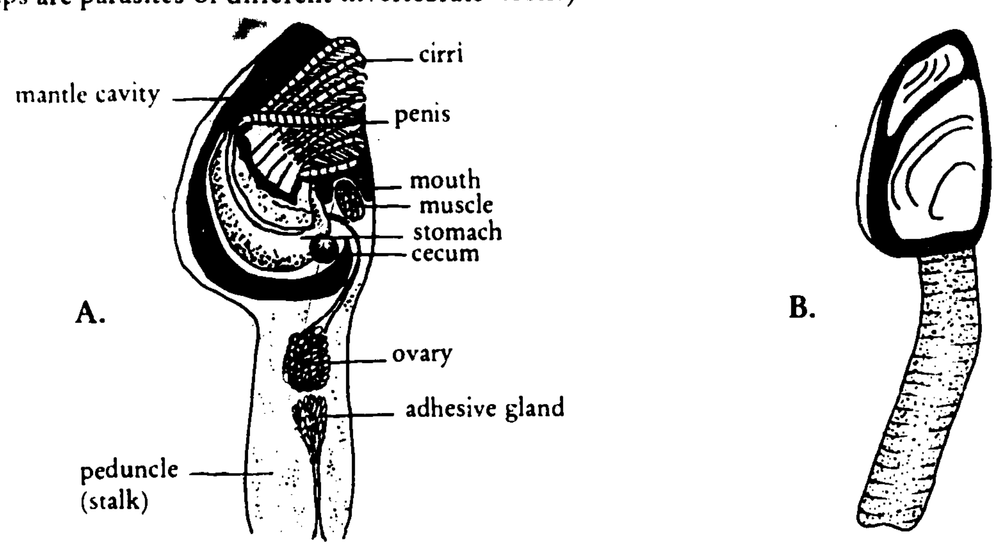


Figure 1. Goose-Necked Barnacles. A, Internal anatomy of the barnacle. B, External view of the barnacle.

Louis Agassiz, a famous naturalist, described acorn barnacles as "nothing more than a shrimp-like animal standing on its head in a limestone house and kicking food into its mouth". In becoming permanently attached to a solid surface by its head, the acorn barnacle has lost both the eyes and antennae found in more typical crustaceans. During feeding, the six pairs of appendages act as a unit: the protective valves separate, the feathery legs are thrust out, swept through the water and drawn back inside the valve, immediately carrying the trapped plankton inside the body. This action is repeated every few seconds.

Barnacles are **hermaphrodites**; that is, each barnacle has both male and female reproductive organs (Figure 1A). Even though this is true, cross-fertilization rather than self-fertilization, usually occurs. **Fertilization** takes place when the slender contractile sperm tube of one barnacle is thrust through the shell valves into a neighboring barnacle. Within the parent, the fertilized eggs develop into larvae and after hatching become free-living members of the **zooplankton** for a few weeks. Here they develop into the larval stage that eventually attaches to a suitable hard surface. The larva uses a sticky cement to attach itself. Soon after this process occurs, a calcium carbonate skeleton is started at the base and sides of the organism.

Some kinds of barnacles always live in the **littoral** zone below the **low-tide line**; others are found at greater depths; still others live only intertidally and are able to tolerate temporary exposure at low tide. Acorn barnacles withstand exposure when the tide is out by means of the wall of calcium carbonate plates which enclose the base and body. Also, the pair of valves at the top of the barnacles's body can be virtually sealed when necessary (Figure 2A). Acorn barnacles have a variety of enemies, particularly various kinds of snails. Sea stars (starfish) also feed on barnacles when other, more attractive food cannot be obtained. In their planktonic larval stages, barnacles are eaten by larger zooplankton and by different kinds of fish.

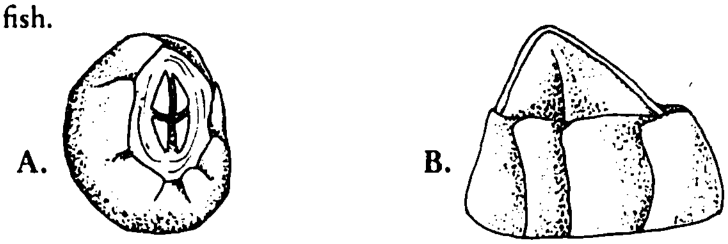


Figure 2. Acorn (Rock) Barnacles. A, Dorsal surface of barnacle showing valves. B. Lateral view.

The number of individual barnacles in a given area can be enormous. This kind of supercrowding tends to cause smothering, and together with the competition sometimes offered by other organisms causes considerable death of barnacles. The barnacles higher up on the shore grow slowly and live about five years while the faster growers farther down may die after three years. In any intertidal area the smallest barnacles are invariably the youngest.

Barnacles, as **fouling** organisms, make a costly nuisance of themselves on ship bottoms, pilings, and various marine hardware. Before the development of anti-fouling paints, ships had been found to carry as much as 300 tons of these fouling organisms. Barnacle accumulations on hulls reduce the ship's speed considerably, increase fuel consumption, and cause frequent and costly docking. It has been estimated that the annual cost of barnacle fouling to the shipping industry in this country amounts to more than $100 million.

VOCABULARY

Appendage—an outgrowth of the body of an animal.
Chitin—a carbohydrate material in the exoskeleton of arthropods.
Cirrus—a type of appendage which is used for scooping plankton from the water.
Fertilization—the union of a sperm with an egg.
Fouling—the process of physically defacing an object.
Hermaphrodite—an organism which has both male and female reproductive systems.
Intertidal—in the marine environment, the area of the shore that is periodically covered and uncovered by water.
Littoral—an area extending from shoreline to the edge of the continental shelf or to the 200 meter depth line.
Low-tide line—the lowest level of a shoreline to be exposed during low tide.
Subtidal—the area of the beach that lies below the tide line.
Zooplankton—microscopic or nearly microscopic free-floating aquatic animals that feed on other forms of plankton.

Activity: Anatomy and Feeding Behavior of Barnacles

Objectives

To investigate shell composition of an acorn barnacle.
To become familiar with the internal anatomy of an acorn barnacle.
To investigate the behavior of a barnacle when exposed to various stimuli.
To observe the feeding behavior of an acorn barnacle.

Materials

acorn barnacles (living and preserved), medicine droppers, pliers, probes, tweezers, dissection pans, crushed barnacles, vinegar (weak acetic acid), hand lenses or dissecting scopes

Procedure

I. Anatomy of a Barnacle

Examine a preserved acorn barnacle. The opening at the top of the shell is closed by movable plates. How many of these plates are present on your specimen? ____________________ When the plates are "closed" the barnacle is protected both from its enemies and from drying out when exposed to the air. Now examine the plates that make up the barnacle's shell. How many of these plates are present? __________ Of what material do you think these plates are composed? (Hint: Think about possible chemical compounds.)____
Reaction with acetic or hydrochloric acid is a common test for the substance which makes up these plates. Place a few drops of acetic acid on one of the plates. Record your observations.____
____

Barnacles are not the only marine organisms that use this chemical compound in their shells.

Remove the barnacle from its shell in order to study its internal anatomy (Figure 1). A pair of pliers will be useful in cracking the shell. Be careful not to crush the barnacle. A probe and tweezers will aid in removal of the animal. In what position was the barnacle oriented while in its shell? ______________________________

Examine the spines on the **cirri** (Figure 1). How are these useful in collecting food? ______

____

Locate the mouth and then identify the digestive tract. You may be able to find some eggs attached to the body of the barnacle. Body fluids flow inside the animal by ordinary muscular movements.

II. Feeding Behavior of a Barnacle

If living barnacles are available, you can easily observe their feeding behavior and their responses to other types of stimuli. Test the feeding barnacle for response to a stimulus by causing a shadow to fall across the animal or by touching the cirri. Record your observations. ______________________________

____

Crush a few barnacles and very carefully deposit a few drops of the resulting fluid near a feeding barnacle. How does this affect the action of the cirri? ______________________________

____

Extending Your Thoughts

Do you think that the temperature of the water has any effect on the feeding behavior of barnacles? (To answer this question, design an experiment that uses water at various temperatures.)

VOCABULARY

Cirrus—a type of appendage which is used for scooping plankton from the water.

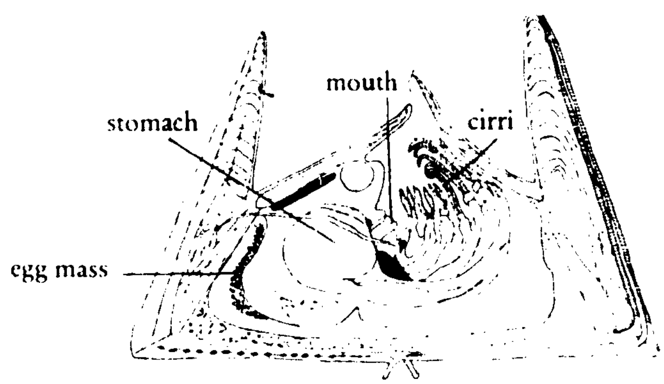


Figure 1. Acorn Barnacle *(Balanus)*. Cross section through the barnacle, illustrating various internal organs.

CONCEPT I

The blue crab is economically important as a source of food. Hermit crabs, though not valued as highly, are interesting to observe in nature.

Objectives

Upon completion of this concept, the student should be able:

a. To list three to five external characteristics of the blue crab.
b. To explain the method of growth that occurs in blue crabs.
c. To list some of the natural enemies of the blue crab, other than man.
d. To summarize the reproductive process in blue crabs.
e. To explain the consequences of growth in hermit crabs.
f. To discuss the relationship that exists between a hermit crab and a sea anemone attached to the crab's shell.

THE CRABS (PHYLUM ARTHROPODA, CLASS CRUSTACEA)

Blue Crab

One of the most handsome and most delicious animals to grace the bottoms of the shores, estuaries, and bays in Mississippi and Alabama is the colorful blue crab, *Callinectes sapidus,* (Figure 1A). (The generic name, *Callinectes,* is a combination of two Latin words meaning "beautiful swimmer".) It is an arthropod which, together with the other edible crabs, shrimps, and lobsters, belongs to the most highly developed order of Class Crustacea.

At first glance, a blue crab seems to bear little resemblance to a lobster or a shrimp. When the flattened abdomen that is normally turned under the body is extended; however, common characteristics that demonstrate a relatively close relationship are revealed. Among these are the hardshell covering of each of the segments. This hard covering is important since it forms a jointed protective **exoskeleton.** Thin, soft areas between the segments allow the organism to move about. The crab's stalked **compound eyes** are controlled separately and can be laid back into sockets in the shell at the front of the head when injury threatens. Passing a shadow across the eye is sufficient stimulus to trigger this protective reaction. The eyes probably form only a very crude image but are exceptionally good in determining both the movement and location of an object.

The crab's **appendages** perform a number of functions, including biting, fighting, grasping, walking, etc. The first three pairs of appendages located on the thorax are modified as **maxillipeds.** There are five pairs of walking legs located posterior to the maxillipeds. The specialized first pair of legs, the **chelipeds,** has a terminal segment, a claw. This enables the crab to thrust the leg outward and clamp down on any object that threatens the crab. The fifth pair of legs, which consists of segments that are broad and flattened like paddles, is used as oars. This pair of swimming legs enables the blue crab to move rapidly through the water. Leg modification for swimming is an interesting adaptation since close relatives of the blue crab have to get about as best they can by running. With so many appendages to work with, the crab has available almost any tool it needs.

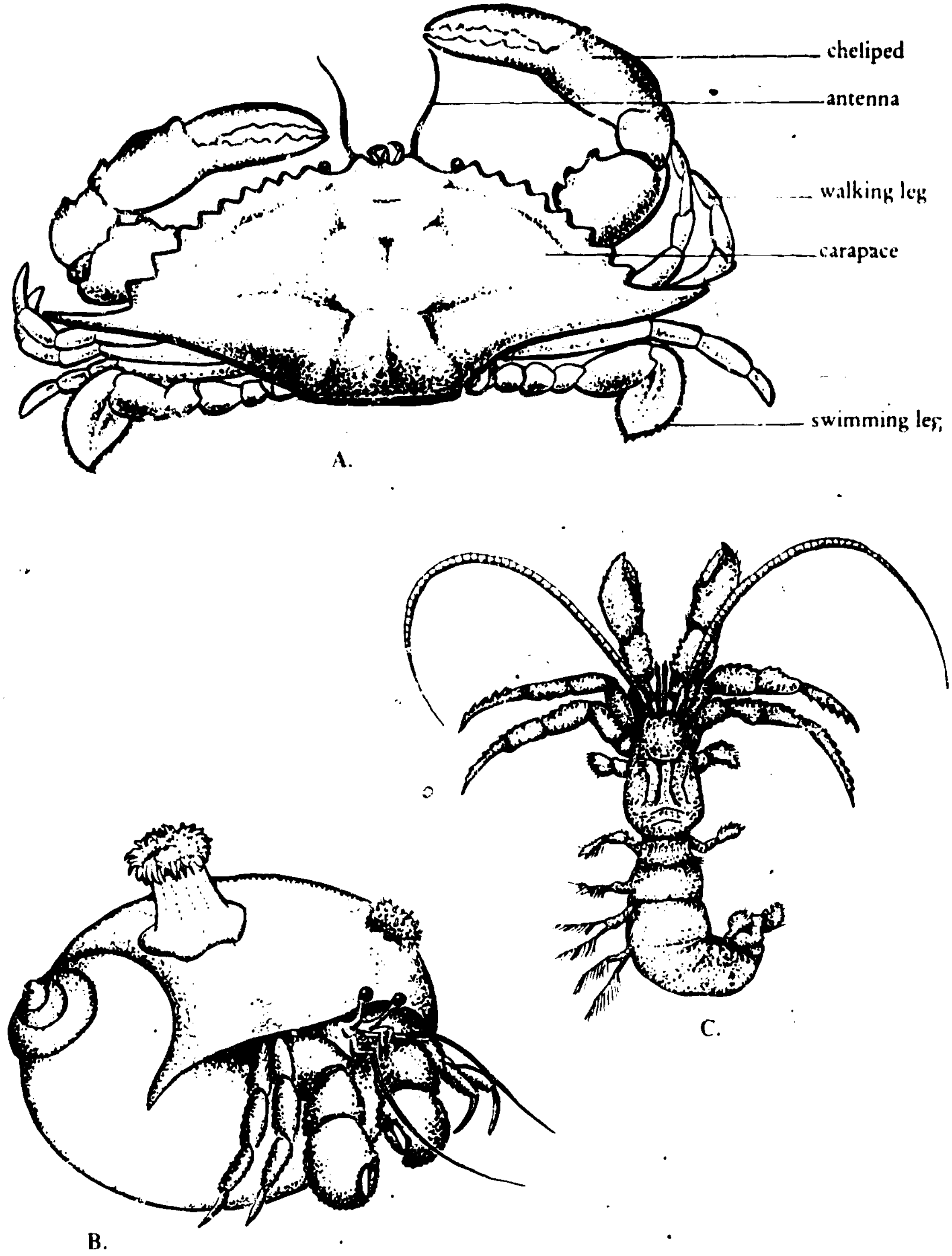


Figure 1. A Blue Crab *(Callinectes sapidus)*. B, Hermit Crab (in shell). C, Hermit Crab (removed from shell).

The blue crab and its relatives can throw off their legs and grow new ones. This undoubtedly provides a good method of escape from enemies. Extreme contraction of muscles in the second joint allows removal of a particular leg. The nearly colorless blood coagulates quickly and the wound closes rapidly. A new leg begins to grow at once from a bud beneath the scar. After a few molts it closely resembles the original leg.

A crab grows by shedding its old, hardened exoskeleton and forming a new, larger one. This process is called **molting.** During molting, the **posterior** part of the body protrudes through a gap made by cracks in each side of the shell. It takes about 15 minutes for the crab to free itself of the old shell. After shedding the new skeleton is soft and pliable. The soft skeleton is stretched to accommodate the increased size. Usually the crab will take in water or air during this period to expand its body. In about 48 hours the new exoskeleton hardens. Often the crab will contribute to the hardening process by eating its own shell and in this way gain calcium carbonate needed to harden the new s[illegible] At the time of molting, the blue crab is virtually defenseless and cannot eat. Molting [illegible]urs every few weeks while the crab is young; later, shedding may take place no more than once a year.

The sexes in blue crabs are separate. One can easily distinguish male from female since the larger male crab, commonly about 17 cm wide, has a sharply pointed abdomen, while the female's abdomen is well rounded. The mating season for blue crabs in the Mississippi Sound extends from March through November. The female mates only once—while she is in the soft shell stage at the time of her final molt. Prior to the final molt, the male crab carries the female crab beneath him until she has shed. During the mating activity, the female crab stores the sperm that is released by the male. After mating, the male continues to protect the female until her shell has hardened. The female now begins a migration to waters of high **salinity** carrying her fertilized eggs as an egg mass cemented to hairs that project from her **swimmerets.** This egg mass may contain from 50,000 to 2,000,000 eggs. In this condition a crab is said to be "in sponge". The eggs hatch directly into high salinity waters. The **larval** stages are all spent floating about as members of the **pelagic zooplankton.** Only a very few of the tens of thousands of larvae originally released by a single female ever grow to maturity

Blue crabs feed on a great variety of living plants and animals. However, their main food seems to be dead animals. Crabs can strike with their large specialized first pair of walking legs, chelipeds, by suddenly thrusting them outward, and closing down hard with the pointed tips of their viselike claws. The painful bite seldom does more than draw blood. It can be avoided if the crab is grasped between the bases of the swimming legs by thumb and forefinger.

Blue crabs have several enemies in addition to man. They are hunted along the shores and in shallow water by gulls and herons. In deeper waters they fall victim to octopuses and to fish with teeth sharp enough to crush them. The blue crab, like other crabs, retreats to deeper offshore waters during the winter months.

Commercial landings of blue crabs in Mississippi were recorded for the year 1887 as 38,000 pounds. Mississippi landings have averaged over 1,700,000 pounds a year from 1964 to 1974, but with large year-to-year fluctuations. These fluctuations reflect economic conditions of the market as well as variations in abundance due to environmental factors such as temperature, salinity, prevalence of disease and predation.

Hermit Crab

The hermit crab is abundant along the water's edge, living on pebbly, sandy and muddy bottoms, in tide pools, behind sand bars, and in other shallow relatively unexposed areas (Figure 1B).

The outstanding visible feature of the hermit crab is its shell. The shell is not part of the crab's body but belonged to a snail that had died before the crab found it. The shell protects the soft rear end (abdomen) of the hermit crab (Figure 1C). In taking a shell, the crab first explores it thoroughly inside and out with claws and feet, probably to make sure it is not occupied. After this exploration, it makes the change from its current shell to the new one.

Hermit crabs use the empty shells of snails and whelks. Apparently it is not the type of shell that is important to the crab, but more its size and availability. As the crab grows, the shell must be discarded for a larger one. If the new shell becomes unsuitable, the crab immediately will change back to its old home and take up the search for new housing once more.

Because the body of the hermit crab is a spiral that fits the central spiral column of the shell, it is very difficult to remove the animal from the shell by just pulling it. In addition, the last pair of appendages on the abdomen is modified in the form of a clamp, thus adding to the crab's ability to maintain its position in the shell.

As in other crabs, the eggs of the hermit crab are fertilized before they leave the body of the female. As the eggs are expelled by the female they are attached to small appendages of the tail by a sticky material that she produces. However, because of the spiral curve of her body they are cr[illegible]d on the left side of the abdomen rather than in the center as in other kinds of crabs. The eggs of hermit crabs are often brilliantly colored in various shades of orange or dark purple.

Male hermit crabs are fond of fighting for the favor of the more desirable female hermit crabs. After beating down the opposition, a male will probably drag the shell of a female until she is ready to shed. After this happens he immediately deposits his sperm inside her shell and onto her abdomen. This insures fertilization of the eggs as they emerge.

Ecologists have observed that shells occupied by hermit crabs are often unusually suitable places for the settling of a variety of other organisms. In one case there is a species of hermit crab that is always found with a sea anemone attached to its shell. The anemone has a broad base which is wrapped around the shell. Its mouth, surrounded by tentacles, is on the underside next to the shell opening. Presumably the anemone gives protection to the hermit crab and, in return, shares in gathering up the bits and pieces from the hermit crab's meals. When the hermit crab moves to a new shell it removes the anemone from the old shell with its claws and places it on the new shell.

In another example, the smooth rounded yellow lumps of a particular species of sponge dredged from a few fathoms of water may have a round opening in which the claws of a small hermit crab can be seen. When the sponge is cut open the body of the hermit crab may be found resting in a spiral cavity at whose apex is the remains of the shell. The sponge settled on the shell and eventually dissolved the shell.

Hermit crabs often have colonies of small hydroids, particularly those of the genus *Hydractinia* attached to the shells they carry, giving the shells a sort of velvety appearance when the hydroid individuals are expanded. These species of hydroids may also be found attached to rocks and to sea weeds. Other organisms that may settle on hermit crab shells are barnacles, flattened limpet types of mollusks, and algae. In these cases, no special types of relationships have been observed between these occasional settlers and the hermit crabs.

As might be imagined, zoologists interested in investigating animal behavior have paid considerable attention to the biology and activities of hermit crabs. A relatively large amount of literature is ~~being~~ accumulated in research libraries of the world concerning these active and apparently always busy little animals. Many Italians have given such investigations a more personal and practical touch by cooking the crabs in oil. When done they are served in the shell and taken out with a pin or a toothpick to be eaten.

VOCABULARY

Appendage—an outgrowth of the body of an animal.
Cheliped—a claw-foot used in food-getting and for protection.
Compound eye—an eye composed of numerous lenses and containing separate nerve endings.
Exoskeleton—the hard outer covering or skeleton of certain animals.
Fertilization—the union of an egg with a sperm.
Larva—an immature stage in the life of an animal.
Maxilliped—a crustacean thoracic appendage typically used for holding food.
Molting—process of shedding the exoskeleton in arthropods.
Pelagic zooplankton—tiny animals floating in the upper water column of the ocean.
Posterior—the hind end of an organism.
Salinity—a measure of the total amount of dissolved salts in seawater.
Swimmerets—appendages on the abdomen of a crustacean.

Activity: Hermit Crab Behavior

Objective

To become familiar with the habits of one of the more common marine crustaceans, the hermit crab.

Along with crayfish, crabs, lobsters and shrimp, hermit crabs are members of class Crustacea in phylum Arthropoda. The ordinary hermit crabs are very common on every coast. Two of the very common hermit crabs found along the Gulf Coast are *Pagurus pollicaris* and *Clibanarius vittatus*. These organisms have well-developed, soft, and somewhat coiled abdomens that are inserted into empty mollusk shells. They carry these shells around on their backs so that they can retreat into them for protection when attacked. **Appendages** found on the left side of the sixth abdominal segment of the hermit crab are adapted for holding onto the **columella** or central support of the shell.

Since hermit crabs are very active organisms, most people take an interest in them. These organisms can be found in the area between the **high and low tide lines** along the beach. You may capture these marine inhabitants with a dip net or simply by picking them up with your hand.

Part I: Making a Hermit Crab Pan
Materials (per group of four students)

container, hermit crabs, empty shells, sea water, paper towels

To observe the hermit crab successfully you will need to make a hermit crab pan. Obtain a flat, rustproof container which will hold clean sea water up to a depth of one to three inches. (Glass, porcelain, or plastic containers seem to work best.) Once you establish a water level, mark the level with a grease pencil. As water evaporates, refill the pan to the original level by adding fresh tap water. When evaporation is rapid it is difficult to control the **salinity**; therefore, empty the container each week and start again with fresh sea water.

You may find that the hermit crab will try to get out of the container. It may be necessary for you to devise a "fence" to keep it in the pan. Also, if the hermit crab is young you may need to find additional larger shells.

The animal can be fed using bits of frozen shrimp and fish food. This material should not be left in the water for a long period of time since it will pollute the water. Remember that hermit crabs are **scavengers**; consequently, they will eat a wide variety of materials.

Part II: Behavior of the Hermit Crab
Materials (per group of four students)

hermit crab pan, sea water, paper towels, hand lenses, empty shells of all sizes

Objective

To devise experiments which will provide information about the behavior of hermit crabs.

Procedure

In your group of four students devise experiments which will provide answers to the following questions.

1. How do hermit crabs move?______________________________________
____
2. How do they use their legs in walking?____________________________
____
3. Do you think hermit crabs move fast or slow?________________________
What was the basis for your response?_____________________________

Conduct an experiment to determine if hermit crabs walk differently on different surfaces.

4. What kind of surfaces did you try?________________________________
____
5. What did you find out?____
____
6. What happens to the hermit crab on the edge of your desk? (Be careful and don't let it fall).____
7. What does your hermit crab seem to like to eat?______________________
____

8. What is the most interesting behavior that you have observed about your hermit crab? ____

____

9. Do all of the hermit crabs in the room seem to be of the same species? __________ ______________________ Explain ______________________

____

Part III: House Hunting
Materials (per team of four students)

hermit crab pan, sea water, extra shells, cigarette lighter, large flat sponge, 2 hermit crabs

Objective

To observe the hermit crab as it selects a shell and establishes a new home.

Procedure

Select one of the hermit crabs that has established itself inside a shell and place it on a wet sponge. Allow the crab to become accustomed to the new conditions. Strike the lighter and heat the SPIRE of the shell containing the crab. The heat will cause the crab to leave the shell. The wet surface of the sponge will also lure the organism out of the old shell. Do not move the shell or the crab will not come out, even if you burn him.

Remove the other hermit crab from its shell by using the same technique. Once both crabs are freed from their old shells; place them in the hermit crab pan. Place one shell in the pan and observe the behavior of the crabs as they both compete for the same shell. Note their behavior as they measure the shell for a possible home.

Can you predict which crab will secure this particular shell for a home? ______________________ Were you correct? ______________________

Does the loser seem to exhibit submissive behavior? ______________________

Explain. ____

____

Now provide another shell of adequate size. Does the other crab seem interested? ______________________ Discuss the observed behavior.

____

____

____

Part IV: Anatomy of the Hermit Crab
Materials (per team of four students)

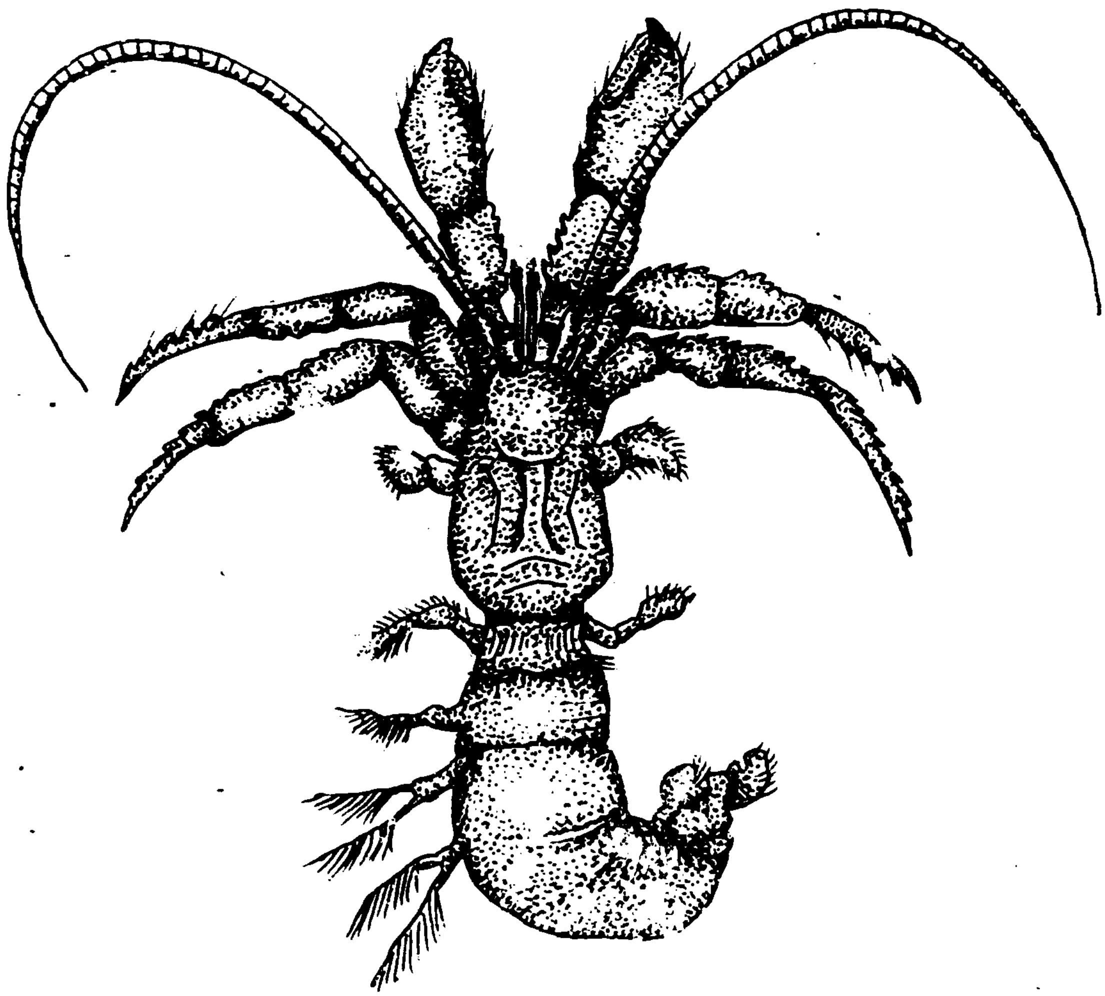
hermit crab, hermit crab pan, sea water, paper towels, sponge

Objectives

To identify the major parts of the hermit crab.
To compare the major parts of the hermit crab with those of other common crustaceans.

While you are waiting for the hermit crabs to select a new home, make appropriate anatomical observations to respond to the following questions.

1. What are the major body parts of the hermit crab?____________________________________
2. Are these the same as for other crustaceans?____________________________________
3. What parts of the crab are visible when the crab is walking around in the shell?________
4. What parts are always covered when the crab is walking around in the shell?
____
5. On the following drawing label these parts: walking legs, abdomen, carapace, pleopods, telson, eyestalk, antenna, cephalothorax, antennule, and chelipeds.



6. How are the pleopods used by hermit crabs?____________________________________
____
7. How does the hermit crab use the modified walking legs?________________________
____
8. How does this organism compare with other common crustaceans?__________________
____
9. What kind of shells was preferred by the hermit crabs that you used in these lessons?____

VOCABULARY

Appendage—an outgrowth of the body of an animal.

Columella—in gastropod shells, the central axis of the shell around which the whorls are spiraled.

High tide line—the uppermost level on a shoreline to be reached by the highest tides.

Low tide line—the lowermost level on a shoreline that is reached by the lowest tide.

Pleopod—an abdominal appendage on a crustacean, which may be used for swimming, respiration, or holding eggs.

Salinity—a measure of the total amount of dissolved salts in seawater.

Scavenger—an animal which feeds on the dead remains of other animals and plants.

Spire—the part of the gastropod shell preceding the body whorl.

Activity: Marine Organisms and Osmotic Tolerance

Objectives

To determine if salt concentration has an effect on the quantity of water that an organism contains.

To determine if various species of an organism will respond in the same manner to a change in a physical factor such as salt concentration.

Many marine animals have a high tolerance for **salinity** changes. This is called **osmoregulation.** The organism must have an **adaptation** that will allow for these external environmental changes. On the other hand, there are some organisms that have very little ability to adjust to a change in an environmental factor such as salinity. Organisms that can be found in the **estuarine environment** probably belong to which of these two groups? ________. How could you design an investigation to test your prediction? One simple method of determining the osmoregulatory abilities is to compare weight changes in some organisms over a period of 24 hours. If an organism can maintain its weight when placed in different salt concentrations, the organism must have a fairly well-developed osmoregulatory mechanism. Conversely, a tremendous weight change indicates that the organism is not able to tolerate much of a salinity difference.

Materials (per team of four students)

Fresh, live crabs

Procedure

Using Instant Ocean or other synthetic sea salts, prepare solutions of the following concentrations: 5 parts per thousand (ppt), 10 ppt, 15 ppt, 25 ppt, 35 ppt, 45 ppt, 50 ppt. Each of these solutions can be prepared by dissolving the given number of parts of sea salts in 1000 ml of distilled or dechlorinated water. The number of different solution concentrations can be increased or decreased as desired depending upon the number of crabs available for the investigation.

Place a selected organism in each of the containers filled with one of the salt concentrations. At hourly intervals during the day take the crab out, dry it with paper towels, and weigh it. Try to keep all other physical factors constant during the period of investigation.

List some of these physical factors.

______, ______, ______, ______, ______.

Why should they not be allowed to change?______

On the following data table your group should keep an accurate record of the results from one of the salt concentrations. Date ______, common name of crab used ______, salt concentration used ______, beginning weight of crab ______.

Weigh your crab at hourly intervals and record the data in the "mass" column of the table provided on the next page. The column labeled "%" refers to the percent change in mass from one weighing to another. Your teacher will show you a method of calculating these values using the data that you collect.

Weight at the end of the investigation______

Was there a gain?______ How much?______

Was there a loss?______ How much? ______

How can you explain these results?______

______

______

List the various species of crabs used in your experiment ______,

______, ______, ______

Did all of the crabs respond in the same manner?______

Explain______

______

______

How do you think the crab maintains its osmotic balance? ______

______

______

______

	5 ppt		10 ppt		15 ppt		25 ppt		35 ppt		45 ppt		50 ppt	
Hours	Mass	%	Mass	%	Mass	%	Mass	%	Mass	%	Mass	%	Mass	%
1st														
2nd														
3rd														
4th														
5th														
6th														
7th														
8th														
9th														
10th														
11th														
12th														

VOCABULARY

Adaptation—the process by which a species becomes better suited to survive in an environment.

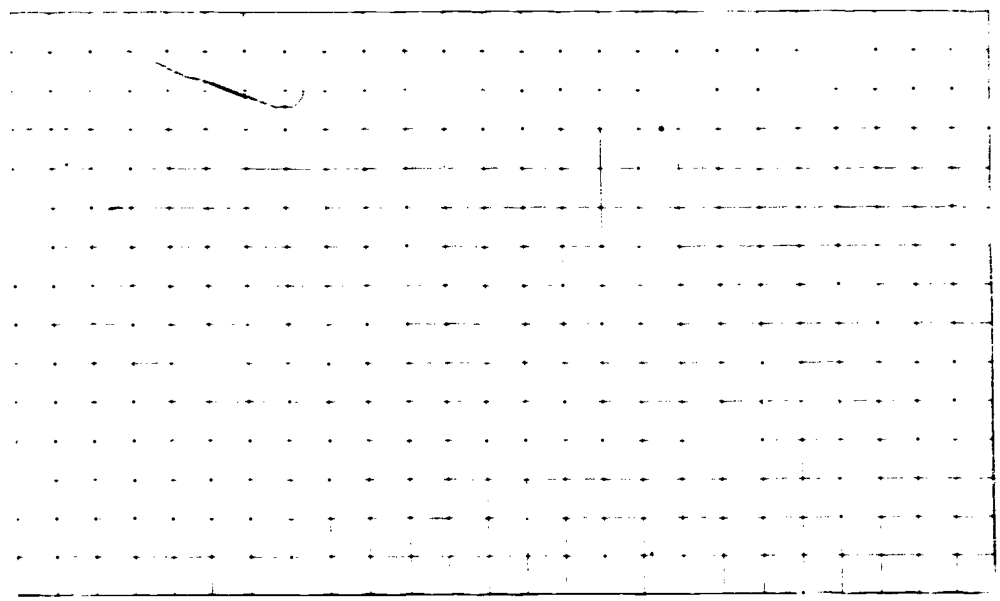
Estuarine environment—situation in which the surroundings of an organism consists of water that is less saline than that in the open ocean.

Osmoregulation—the process by which the osmotic activity of a living cell is increased or decreased by the organism in order to maintain the most favorable conditions for the vital processes of the cell and the organism.

Salinity—the total amount of dissolved salts present in a given amount of substance.

Prepare a graph of your hourly data in the space below

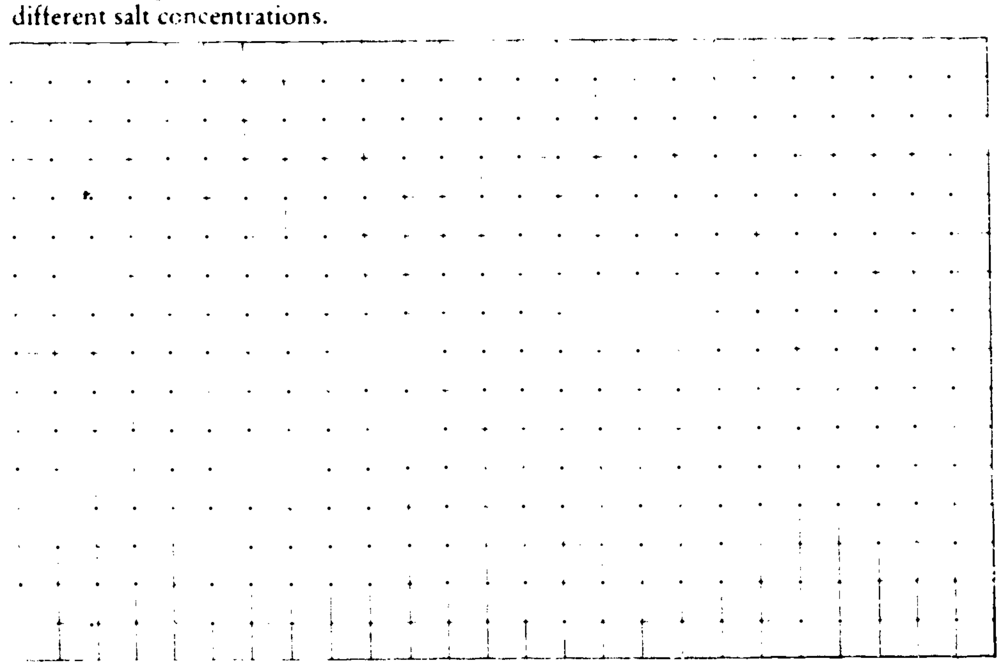
percent change in weight



Hours Observed

Collect the data from all other groups and prepare a graph for the entire investigation. Use different colored pencils for each of the different salt concentrations.

percent change in weight



Hours Observed

Activity: A Study of a Freshwater Crustacean

Objective

To compare the behavior of a freshwater organism with that of a similar marine organism.

What can we find out about the general responses of the crayfish, a very common **crustacean,** to various **stimuli?** What behaviors can we detect when it is compared to the other animals we have studied?

Materials

1 living crayfish, 1 large culture bowl, 1 limestone rock, beef broth, a dissecting kit, chemicals or solutions (India ink, salt crystals, sugar solution, vinegar solution), paper towels

Procedure and Data Sheet for Observations of the Living Crayfish

Fill your culture bowl almost full of water. Place a rock in the bowl and then transfer a living crayfish to this new environment. Record observations about the crayfish's behavior in its new environment. ____________________

____

____

____

Now use your dissecting needle to determine the crayfish's response to touch. What part of the crayfish's body is most sensitive to touch? ____________________

List the locations that you investigated and the reaction at each location.

____

____

____

What did you find in regard to the crayfish's ability to respond to touch?

____

____

____

Use the pinhole flashlight to determine how the crayfish may react to light. What did you observe in regard to the way the crayfish responded to your experiments?

____

____

Is this what you expected? ____________________

Why? ____________________

____

____

What do you think the crayfish eats? ____________________

____________________ Use a dropper to place a few drops of meat juice close to the head of the animal. How does the crayfish respond? ____________________

____

____

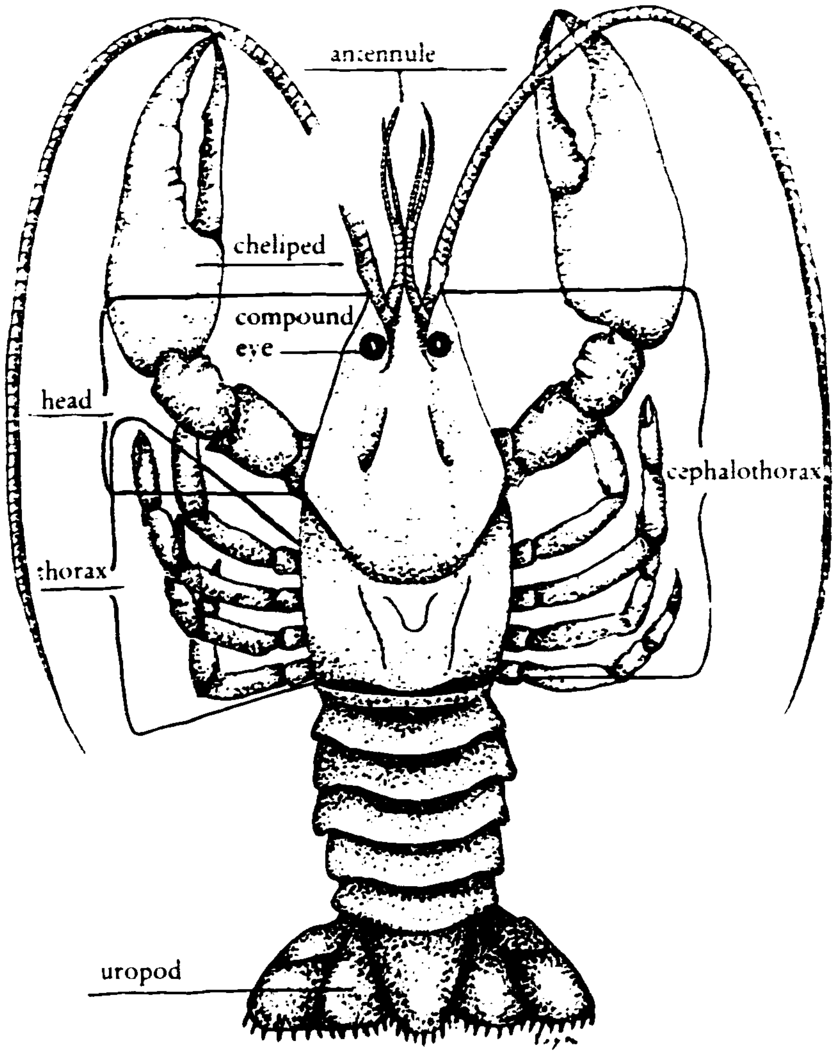


Figure 1. A Crayfish.

Use a few crystals of salt, a few drops of acetic acid, and some sugar solution to determine the reaction of the crayfish to these chemicals. What did you observe in each instance? ____

____

Did you need to change the water for each of these experiments? ______________________ Why? ______________________

____

____

After cleaning your culture bowl once more, place just enough water in the bowl to cover the crayfish. Add one drop of dilute India ink just **posterior** to the **cephalothorax** (Figure 1).

Record your observations.

Why did this happen?

Take the crayfish out of the bowl and place it upside down on some damp paper towels. What happens?

What do you think is responsible for this behavior?

List some of the advancements in structures that might be responsible for many of the behaviors that you have observed today.

Did you have a male or female? How did you know?

How does the behavior of the crayfish compare to that of the hermit crab?

Did you notice any special anatomical **adaptation** in this freshwater organism that has not been as evident in the marine organisms that we have studied?

VOCABULARY

Adaptation—the process by which a species becomes better suited to survive in an environment.

Cephalothorax—the combined head and thorax of some animals, such as crabs and crayfish.

Crustacean—a class of the arthropods; these organisms consist of common marine animals, including shrimp, crabs, barnacles, etc.

Posterior—situated behind or in the rear.

Stimuli—something that stirs to action or effort.

CONCEPT J

Since shrimp are a valuable commercial catch, research is constantly underway to monitor population size and movements of these organisms.

Objectives

Upon completion of this concept, the student should be able:

a. To discuss, in a general fashion, the reproductive process in shrimp.
b. To label a drawing of the external anatomy of a penaeid shrimp when presented with appropriate labels.
c. To explain the effect that inappropriate water temperature and increasing salinity would have on the shrimp population in the Mississippi Sound.

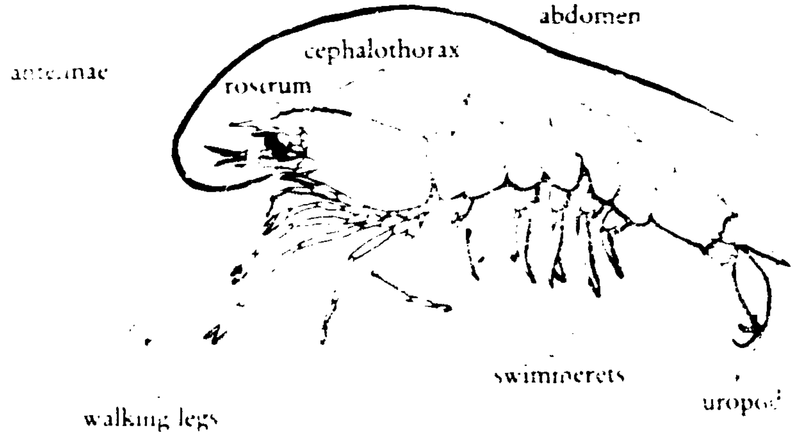


Figure 1. Adult Penaeid Shrimp.

THE PENAEID SHRIMP (PHYLUM ARTHROPODA, CLASS CRUSTACEA)

Although many species of shrimp inhabit the shallows of the coast and deeper waters of the Gulf, few species grow large enough to be utilized for food. Most of those that attain edible size are members of the family Penaeidae, which includes brown shrimp *(Penaeus aztecus)*, white shrimp *(Penaeus setiferus)*, and pink shrimp *(Penaeus duorarum)*. These three species compose most of the commercial catch of the South Atlantic and Gulf shrimp fishery.

Shrimp are crustaceans (from the Latin "crusta" or hard shell). Like other crustaceans, in order to grow this animal periodically sheds its **exoskeleton** when it becomes too small for its expanding body. A new soft shell that has developed under the old one expands and hardens as soon as the old shell is gone.

Like other animals, shrimp have certain identifying marks. Color varies with the kind of bottom the shrimp inhabits and is not a dependable means of identification. However, there are some external differences between brown, pink, and white shrimp.

The external structure of an adult penaeid shrimp is shown in Figure 1. It includes the head spine (rostrum), walking legs (pereiopods), feelers (antennae), swimmerets (pleopods), tail fan (uropods), and tail (abdomen). The internal organs are primarily located in the head section (cephalothorax).

Penaeid shrimp have a complex life cycle. For most of their early life they are almost too tiny to be seen with the naked eye. The young undergo complicated transformations, and their survival depends largely upon remarkable migrations.

Spawning takes place in offshore waters, mostly in the spring and summer though some spawning probably occurs all year. Of the three species, the white shrimp spawns closest to shore, the brown shrimp farthest from shore, and the pink shrimp at intermediate distances. The eggs are laid through openings at the base of the third leg. They are deposited directly into the water, where they are fertilized by sperm from tiny sacs (**spermatophores**) previously deposited by the male in an external female structure called a thecylum. A single female penaeid shrimp may lay between 500,000 and 1 million eggs in a single spawning. Penaeid shrimp release their eggs directly into the ocean. This is in contrast to the method used by other crustaceans. For example, after spawning, crabs, crayfish, and river shrimp carry their eggs attached under the abdomen until the eggs hatch at a later stage of development.

The shrimp eggs hatch into tiny, very primitive **larvae** in about 24 hours. After hatching, they begin to develop through many larval stages during which they are barely visible to the naked eye (Figure 2).

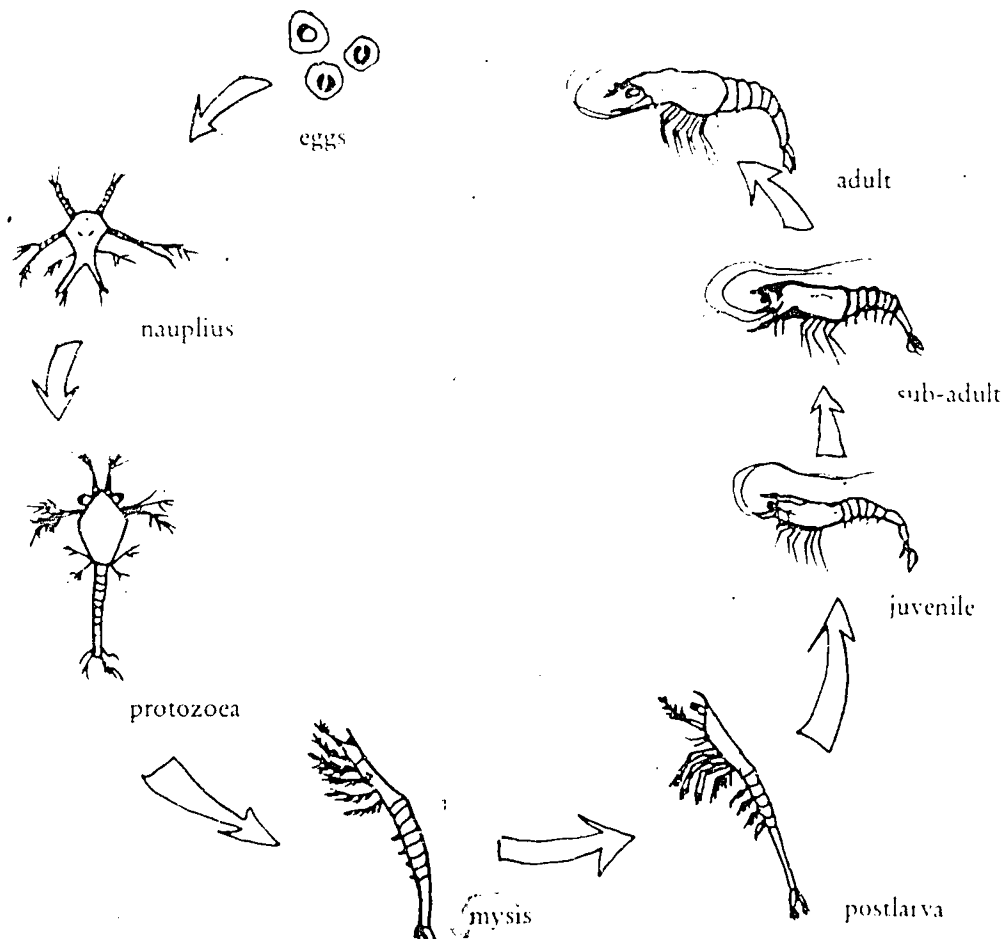


Figure 2. Life Stages of a Penaeid Shrimp.

Peak spawning periods appear to be associated with rising water temperature occurring in the spring, but other factors are involved. It is known that shrimp larvae can survive only in the more constant conditions and relatively high salinity found in offshore waters. However, postlarval shrimp require suitable inshore nursery grounds. They reach the nursery grounds by being borne on favorable onshore currents, a feature of all shrimp-producing areas.

As a larval shrimp is borne along in the water column toward the shore, it develops through five nauplial substages, three protozoel substages, and three mysis substages (Figure 2). A nauplial shrimp does not feed, but utilizes yolk granules which fill the body; feeding starts with the first protozoeal substage. The mysis shrimp has 14 pairs of functional appendages; rudimentary gills have appeared by the second mysis substage and after the third substage, the organism ends its larval phase and assumes the miniature proportions of a slender adult.

At a length of about 5.5 mm (⅜ inch), the shrimp begins its postlarval phase (Figure 2). It enters the relatively shallow estuarine nursery grounds (bays and rivers) when it is carried there by currents. Size varies in Mississippi from about 5.5–12.5 mm (⅜–½ inch), depending on how long postlarvae remain offshore. Until this stage, it has been capable of little directional movement and has led a planktonic or drifting existence.

In the nursery grounds, the tiny shrimp continues changing and after several more molts becomes a juvenile (Figure 2). It is now about 25 mm (1 inch) long and is primarily a bottom dweller. Nursery grounds are characterized by brackish (somewhat salty) to almost fresh water with mud or clay bottom or with submerged grass beds. In such rich feeding areas, when the temperature reaches 20°C (68°F) and above, the young shrimp grow very rapidly. It is estimated that juvenile shrimp grow about 50 mm (2 inches) per month under optimum environmental conditions. Growth rate is affected by temperature and salinity of the water, availability of food and many other factors.

When the shrimp is about 75 mm (3 inches) long, reproductive organs start developing and the juvenile becomes a subadult. As the adults (Figure 2) continue growing and developing, they move offshore toward the more stable temperature and salinity of the dee[illegible]er water of the Gulf.

Because large shrimp disappear from estuaries when they migrate offshore, never returning to the shallow waters, it was once thought that shrimp spawned only once and then died. However, in 1938, concentrations of large shrimp were found in deep waters off the Louisiana coast, and it was determined that many of these "jumbo" shrimp had spawned at least once. Ripe, left-over eggs frequently are found in females, suggesting previous spawning. The percentage of the total population that lives more than 1 year is small; though some shrimp may live 16 months and longer, the crop is considered to be annual.

Because of the long spawning period some young shrimp are nearly always in the nursery area. C[illegible]erable numbers of juvenile white a[illegible] br[illegible] shrimp often remain inshore in the fall and move out only when conditions [illegible] [illegible]able. When water temperature [illegible], the growth of young shrimp in the [illegible] or ceases entirely, whereas the occurrence of protracted periods of warm weath[illegible] [illegible]uring winter months may result in growth in the shrimp.

If the water gets too cold or too fresh during the colder months, all of the shrimp may move out of the shallow areas into nearby waters of the Gulf. The young brown shrimp that move out apparently remain offshore; however, the small white shrimp will return the following spring to the bays to complete their growth before moving out to spawning grounds in late spring or early summer.

In Mississippi waters, brown shrimp postlarvae usually appear in inshore waters in large numbers in March, April and May. There is considerable yearly variation in the time and size of peak spring migrations to nursery areas, depending on the water temperature and number of spawners. A second peak movement shoreward may occur in the fall.

Scientists at the Gulf Coast Research Laboratory carefully follow the movements and growth of the shrimp population. By taking frequent samples of the young shrimp and measuring them, biologists project the growth rate of the population as a whole and determine approximately when the shrimp will attain legal harvesting size. When these projections indicate that 75 percent of young shrimp in commercial fishing areas are approaching 4 inches long (68 whole shrimp per pound), a tentative date for opening the commercial shrimping season is recommended to the Mississippi Marine Conservation Commission.

Bays and bayous and some nearshore areas of the Mississippi Sound are permanently closed to shrimping, except for bait during specified periods, because small shrimp are nearly always present. Brown shrimp postlarvae that arrive in the bays in the spring usually reach harvestable size by early June. However, this harvest time may vary as much as a month.

Large numbers of white shrimp postlarvae usually reach inshore waters in late June and grow rapidly in the bays and bayous. Long after reaching harvestable size, some of the white shrimp often remain in nursery areas where there are many small brown, as well as small white shrimp. Eventually the larger shrimp move out to open water where they may be harvested, leaving the small shrimp to grow.

Pink shrimp provide only a small part of the commercial catch in Mississippi waters. Relatively small numbers of pink shrimp postlarvae and juveniles are found in the fall and summer. They apparently winter offshore and young adults appear in higher-salinity areas of the Sound in the spring.

When the complex life cycle of penaeid shrimp is understood it is clear that destruction of the shrimp at any time during the life cycle could destroy the whole population. Young shrimp in the restricted waters of the nursery areas are particularly vulnerable. Continued shrimp production depends on the maintenance of the environmental conditions of these areas where young shrimp can live and grow.

Carefully regulated harvesting assures the optimum harvest of this most valuable of all living marine fisheries resources. Damage from pollution and destruction of nursery grounds by physical alteration probably constitutes a far more serious threat to shrimp than overfishing the resource.

VOCABULARY

Exo[illegible] outer covering or skele[illegible]

[illegible] ges in the life of an animal.

Salinity—the total amount of dissolved salts present in a g[illegible] ount of substance.

Spawn—to produce or deposit eggs.

Spermatophore—sperm packet.

CONCEPT K

Horseshoe crabs form an important evolutionary link. Currently, they are also the focus of certain areas of medical research.

Objectives

Upon completion of this concept, the student should be able:

a. To explain why horseshoe crabs have the potential to become economically important.
b. To label a drawing of the external anatomy of the horseshoe crab when presented with appropriate labels.

THE HORSESHOE CRAB (PHYLUM ARTHROPODA, CLASS MEROSTOMATA)

The horseshoe crab, *Limulus polyphemus,* which inhabits the Gulf of Mexico and appears along our coast is one of five species of horseshoe crabs in the world. Each year, from August to October, the beaches of the **barrier islands** are covered by hundreds of castoff shells. During the rest of the year an occasional shell can be found washed up on shore. The horseshoe crab, actually not a crab at all, is an example of a "living fossil" since its origin dates back to the time when the first dinosaurs and primitive mammals appeared, about 200 million years ago.

Horseshoe crabs can reach maturity in 9 to 11 years. At maturity the female is equipped with claws; whereas, the males have only a single protrusion which resembles a hook. This appendage is used to grasp the female during the mating act. In the early part of the summer each female crawls up on the beach with a male clinging to her abdomen. After digging a shallow depression near the **high tide line** the female deposits 200–300 eggs which are fertilized by the male as they are laid. The eggs are then covered and the parents go on their way. In 30–40 days the eggs hatch into **larvae.**

The external anatomy of *Limulus* is interesting to observe. The dome-shaped front of the shell, called the **carapace,** contains four eyes. Two small, simple eyes are located on the **anterior** portion of the carapace and two larger, **compound** eyes are also present (Figure 1A). The pair of compound eyes is thought to react to polarized light and to aid in navigation. Located on the **ventral** surface of the abdomen are five large flaps or **gill books.** They get their name from the fact that under each flap are up to two hundred "leaflets" which are, in reality, the gills (Figure 1B). The total surface area of these structures is sufficient to allow the exchange of oxygen and carbon dioxide. In addition to permitting exchange of these gases, the gill books can sometimes be used by the animal as paddles while swimming upside down in the water. The tail or telson of the horseshoe crab is not a weapon. Rather, it is used to help propel the organism through the sand and to assist the animal in righting itself should it be knocked upside down by a wave. The last pair of legs are also quite useful in movement since they are modified to consist of a series of spines or stiff flaps which are used in a manner similar to ski poles.

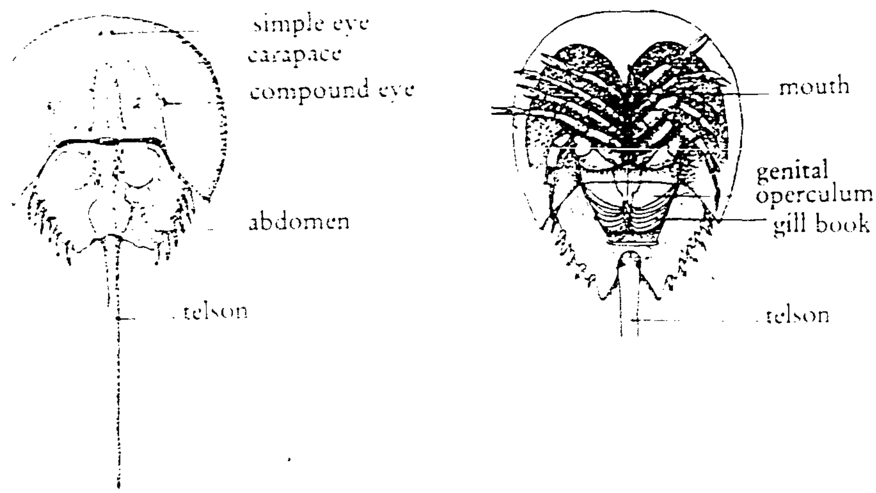


Figure 1. Horseshoe Crab. A, Dorsal view. B, Ventral view.

Like other arthropods, *Limulus* has a hard outer shell called an **exoskeleton.** In order to grow, this animal must periodically shed (molt) the exoskeleton. Many of the "dead" horseshoe crabs that are found on the beach are not dead animals. In actuality they are the cast-off shells of molted horseshoe crabs. Once a horseshoe crab sheds its old shell, it has a new, soft one which hardens in about 12 hours.

Limulus is a true "blue blood" for, while human blood is red, the blood of this creature is a light blue. Human blood is red because it has a red pigment called hemoglobin which contains iron. Horseshoe crab blood contains copper rather than hemoglobin thus giving the blood its blue color. A recent discovery in the field of medicine has made this blood valuable. It seems that a certain component in *Limulus'* blood is extremely sensitive to **endotoxins.** This blood component has been called **lysate.** When blood from the horseshoe crab is mixed with an endotoxin, the blood clots. Any medicine that is to be administered to humans can be checked for the presence of endotoxins by mixing some of the medicine with lysate. If endotoxins are present in this sample of medicine, they will react with the lysate. This reaction indicates that this particular sample of medicine should not be given to humans. The lysate used in this test sells for several thousand dollars per liter.

The diet of *Limulus* consists of mollusks, worms, and other invertebrates that the animal finds while walking along the bottom of the Sound or while digging through the sand. At times these animals are serious predators on clam beds along the northeastern coast of the United States. Consequently, horseshoe crabs are considered pests and are destroyed in large quantities, being ground up for fertilizer or chopped up and used as bait in trapping conches and eels. Other horseshoe crabs are killed by people who are afraid of the animal. Reduction in the number of horseshoe crabs through these practices has placed this ancient animal in danger of becoming extinct.

VOCABULARY

Anterior—front part of an animal.

Barrier island—a long, narrow island parallel to and not far from a mainland coast. The island is composed of material heaped up by ocean waves and currents.

Carapace—the hard-shield covering on the back of animals such as a crab, lobster, and turtle.

Compound eye—an eye composed of numerous lenses and containing separate nerve endings.

Endotoxin—bacterial by-products that are very poisonous to humans.

Exoskeleton—the hard outer covering or skeleton of certain animals.

Gill books—large flaps which cover the gills. They are found on the posterior portion of the horseshoe crab shell.

High tide line—the uppermost level on a shoreline to be reached by the highest tides.

Larvae—immature stage in the life of an animal.

Lysate—a component of the blood of horseshoe crabs which is useful in screening medicines for the presence of endotoxins.

Ventral—the underside of an organism.

CONCEPT L

The sea squirts, and tunicates in general, are a rather unique group of organisms since they form a developmental link between the invertebrates and the vertebrates.

Objectives

Upon completion of this concept, the student should be able:

a. To list the three characteristics that are common to all members of the phylum Chordata.
b. To describe the developmental process in sea squirts.

THE SEA SQUIRTS
(Phylum Chordata, Subphylum Urochordata)

Tunicates are all relatively small marine animals. The tadpole-shaped larval form of a tunicate possesses the three characteristics that are common to all members of the phylum Chordata (Figure 1). These include: a dorsal, tubular nerve cord, a **notochord,** and gill slits. When the **larvae** cease swimming around actively, they become attached to a stationary **substrate.** The **sessile** larva develops into a simpler, bag-like form representing the adult tunicate (Figure 2). During this process of development, the larval tunicate gradually loses its dorsal nerve cord and notochord. It is important to note, however, that gill slits are present in adult tunicates. These structures provide the only link between the adult tunicate and its chordate larval form.

Sea Squirts

The subphylum Urochordata (Tunicata) can be divided into three classes. We shall briefly mention only one class, Ascidiacea. This class includes a group of tunicates that are commonly called sea squirts. Since the adult sea squirts are sessile, they cannot move around to capture their food. These organisms have developed a method of **filter feeding** for obtaining food. A sea squirt forces water into its body through the buccal **siphon.** Food material is filtered out of the water in the **pharynx.** The water is then forced out of the body through the atrial siphon (Figure 2).

Even though these animals appear to be simple, they are rather well-developed creatures. Each sea squirt has a digestive system, a reproductive system, a nervous system, and a circulatory system. Admittedly, these systems are not as complex as those found in higher vertebrates. They do represent significant advancements over systems found in other invertebrates.

Some tunicates may reach more than 12 inches in diameter. The group as a whole has no economic importance.

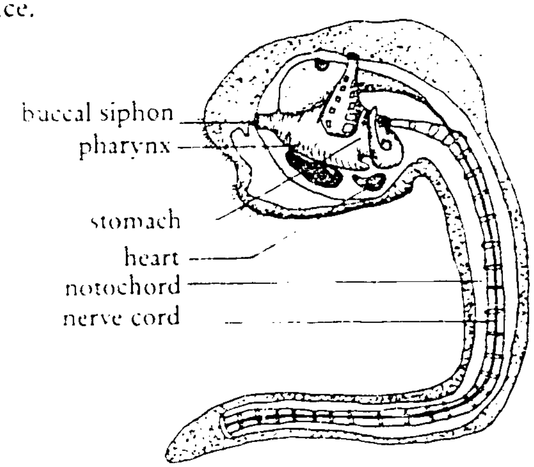


Figure 1. Larval Tunicate.

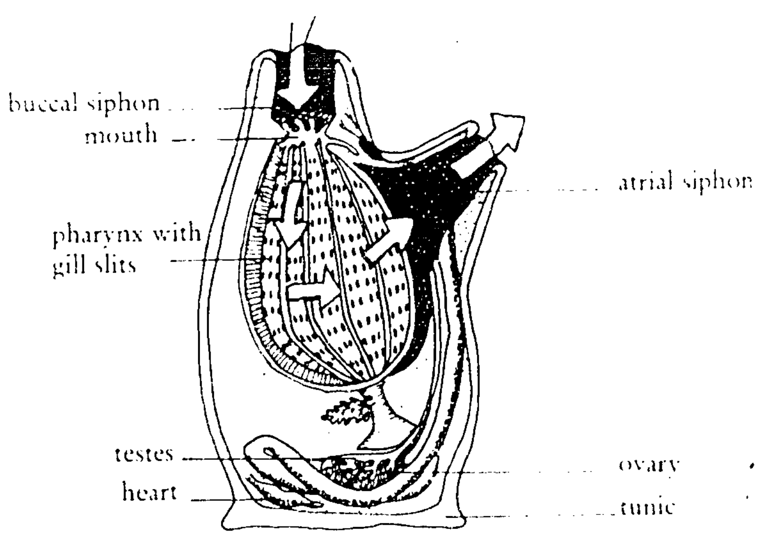


Figure 2. Adult Tunicate. The direction of water flow is indicated by the arrows.

VOCABULARY

Filter feeding—the process of taking food from water as it flows through the animal's body.

Larvae—immature stages in the life of an animal.

Notochord—stiff rod of cartilage along the dorsal side of chordates at some stage of their life cycle.

Pharynx—in tunicates, a structure which filters food from water as it passes through the organism.

Sessile—the condition of being permanently attached to another object.

Siphon—tube-like structures in many organisms which take water into their body where it is filtered for food and oxygen, and also pass out water with excrements.

Substrate—the base on which a plant or animal lives.

CONCEPT M

Sharks and stingrays primarily differ from bony fish in the presence of a cartilaginous skeleton. This "primitive condition" has proved effective for survival.

Objectives

Upon completion of this concept, the student should be able:

a. To name the chief material of which the skeletons of sharks and rays are made.
b. To briefly discuss sensing mechanisms used by sharks.
c. To list some of the uses of shark skin and meat.
d. To explain a method of protection used by the stingray.
e. To explain the safest method of moving through water in which stingrays might be found.

THE SHARKS AND STINGRAYS (PHYLUM CHORDATA)
(Subphylum Vertebrata, Class Chondrichthyes)

Sharks

Approximately one hundred forty million years ago the shark first appeared on earth. Since that time there has been relatively little change in form, indicating that they are extremely well adapted for an existence in the oceans.

Sharks, skates, and stringrays possess a skeleton composed of **cartilage** rather than bone. Some scientists believe that this is a primitive condition, which means that these animals should not be capable of surviving as well as some of the more advanced animals. Evidently the sharks were not informed of this theory since they continue to be one of the very dangerous animals that man is unable to control.

Until recently it was thought that sharks had to swim constantly in order to keep water moving around their **gills**. A television documentary by Jacques Cousteau provided evidence that some sharks do rest on the bottom in an apparent state of sleep. While all sharks may not be capable of performing such a feat, at least there are some species that can breathe while at rest just like any other fish. On the other hand, recently captured sharks usually go into shock and fail to breathe. In this case it is necessary for a human handler to walk the animal in shallow water until it recovers.

Approximately 25 species of sharks inhabit our coastal waters, including the great white shark. The majority of them occur near the passes and channels of the local barrier islands. They are particularly found in this area during shrimping season when the shrimp boats use the lee side of the islands to lay up during daylight hours and dump their waste overboard. For some time it was thought that such actions drew sharks due to the presence of blood. This is not totally true. It has recently been shown that sensory pores on the snout and sides of the shark are acutely sensitive to vibrations. These are the primary detectors of wounded or injured animals. Body juices and blood are the next items to be sensed after the shark homes-in on the vibrations. The final sense used to locate the prey is the eyesight.

For many years scientists have studied sharks with the hope that their findings will allow us to predict the actions of sharks. Many interesting discoveries have been made but it is still not possible to tell with any degree of accuracy what an individual shark will do in a given situation. In some instances a shark will launch an attack and keep pressing it in spite of all efforts to stop it. Other sharks bite only once, then turn and leave. There is more than one case on record where a shark has pressed an attack on an individual member of a group, while completely disregarding others.

Sharks do not react to pain in the same manner as most other animals. In fact, they seem to be immune to pain as we know it. There are many instances where sharks that have been sliced open and returned to the water still alive were observed eating pieces of their own body before dying. The removal of a shark's brain in a laboratory experiment results in an interesting phenomenon. Even though the shark is missing the so-called "control center" it is able to maintain swimming movements for several days. These two instances point to a nervous system unlike that of most animals with which we are familiar.

Man does not allow his fear of sharks to stand in the way of their usefulness. For many years the skin was used for sandpaper and as longlasting leather in the manufacture of shoes. Recently shark meat has gained favor as a source of food in America, but England has long used it as the fish in "fish and chips". At one time there was a great demand for shark livers, which are very rich in vitamin A, but the market disappeared when synthetic vitamins were introduced. Recent research has revealed that sharks have an immunity to many of the diseases suffered by man. This is a curious thing since the shark is never exposed to these diseases.

Stingrays

Left alone and undisturbed most wild creatures are harmless. However, some organisms, like the stingray, possess a strong defense mechanism and are a real danger if provoked. Merely stepping on a stingray that is half buried in the sand bottom of the shallows may be provocation enough for an attack.

The stingray is a fearsome animal that should not be tampered with. Its reputation is well-founded for it can inflict a wound that is extremely painful and slow to heal. Fortunately for the hundreds who suffer wounds each year (stingray wounds are fairly common), permanent or fatal injury rarely occurs.

Large numbers of stingrays are found in Mississippi and Alabama coastal waters during August and September, when female stringrays enter shallow water to bear their young.

Experienced swimmers and waders avoid stepping on the animals by shuffling their feet. When nudged by a foot, a stingray usually skitters away. If a stingray is pinned beneath a well-planted foot for more than a second or two, it will apply its poisonous barb or barbs to remove the offender.

The stingray's barb is located on the upper side of its whiplike tail. The barb, which is composed of a hard bonelike substance called **vasodentine,** is approximately one-third of the distance from the base of the tail in most species. Less than 2.5 cm (1 in.) long in a newly born stingray, the barb may be over 15.2 cm (6 in.) in some adult rays. Dozens of curved serrations line the edges of the barb and it is covered by a sheath containing **venom** glands.

Of the 30 or more known species of stingrays, s[illegible] may be found in waters along the Mississippi Coast. The Southern stingray, *Dasyatis americana,* reaches about 2 m (6.3 ft.) in width. The Atlantic stingray, *Dasyatis sabina,* is relatively small, reaching about 51 cm (20 in.) or so in width. It is abundant in our **estuarine** waters. The Bluntnose ray, *Dasyatis sayi,* may attain a breadth of 0.9 m (3 ft.). This ray is common in **estuaries.** All these rays are flattened fishes, round- to diamond-shaped, with the characteristic whiplike tail. Back colors range from gray to brown and undersides are pinkish-brown. In addition, the Spotted eagle ray, *Aetobatus narinari,* may be seen around the barrier islands. The Smooth butterfly ray, *Gymnura micrura,* and Cownose ray, *Rhinoptera bonasus,* were common in Mississippi Sound trawl collections in the late 1950's but in the 1970's were rarely seen in this area. Figures 1 and 2 provide an idea of what these rays look like.

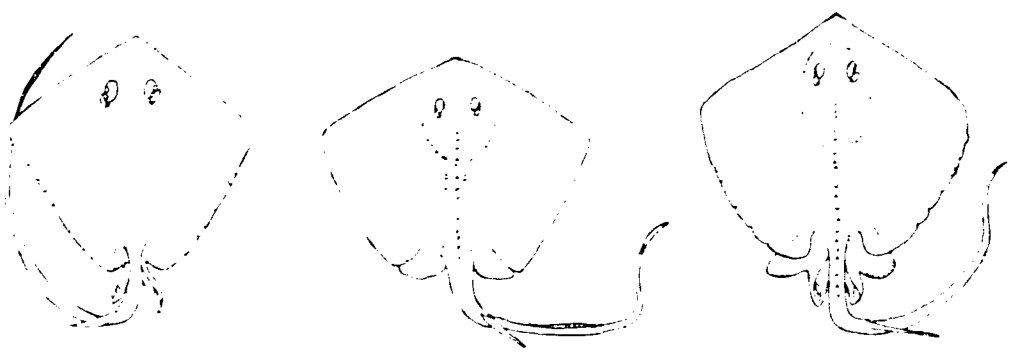


Figure 1. A, *Dasyatis americana.* B, *Dasyatis sayi.* C, *Dasyatis sabina.*

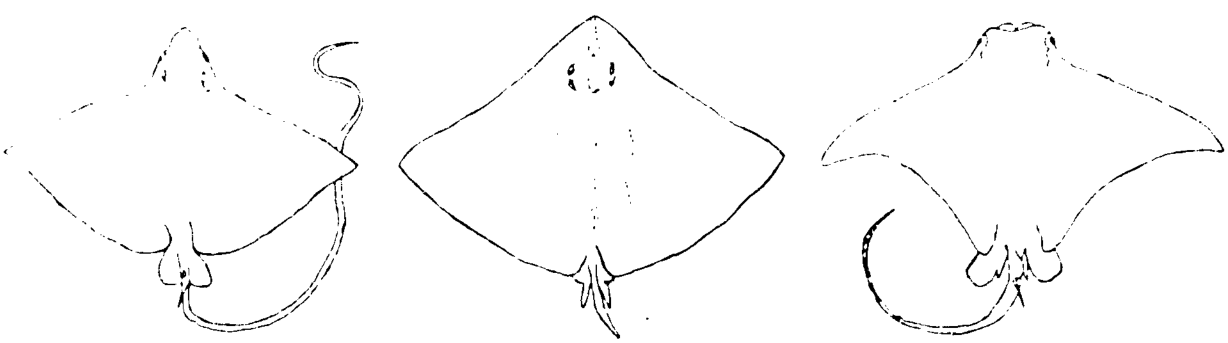


Figure 2. A, *Aetobatus narinari.* B, *Gymnura micrura.* C, *Rhinoptera bonasus.*

VOCABULARY

Barrier island—a long, narrow island parallel to and not far from a mainland coast. The island is composed of material heaped up by ocean waves and currents.

Cartilage—a strong, pliable supporting tissue in vertebrates.

Estuarine—pertaining to an estuary.

Estuary—a relatively small body of water that is set off from the main body of water and is affected by the rise and fall of the tide. Estuaries contain mixtures of fresh and salt water.

Gills—organs which are modified for absorbing oxygen from water.

Vasodentine—a hard bonelike material which makes up the stingray's barb.

Venom—the poison secreted by glands located in the sheath which covers the stingray's barb.

CONCEPT N

The types of common seashore birds found on the Gulf Coast are quite diverse.

Objectives

Upon completion of this concept, the student should be able:

a. To propose explanations for some of the adaptations noted in birds seen on the field trip.
b. To list three characteristics of any particular bird that might be used in its identification.
c. To prepare a listing of the common names, scientific names, and major characteristics of each bird seen on the field trip.

IDENTIFYING SEASHORE BIRDS

If you have visited the seashore, you have probably seen gulls and many other birds. But how many of these birds can you identify? With a little practice and the help of a good bird identification book, you can easily learn to recognize many seashore birds by their size, shape, color, and other distinctive features.

Many different kinds of birds are found along the ocean shoreline—from beaches and marshes to rocky cliffs. A pair of binoculars and some good bird identification books are invaluable companions if you have the opportunity to go to the shore to observe birds. Four books that may be helpful in bird study include:

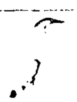
Bull, J. and Farrand, J. *Audubon Society Guides to North American Birds: Eastern Region.* New York: Knopf, 1977.

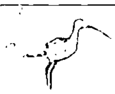
Palmer, E. L. and Fowler, H. S. *Fieldbook of Natural History*, 2nd ed. New York: McGraw-Hill, 1975.

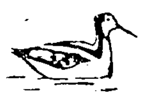
Peterson, R. T. *A Field Guide to the Birds.* Boston: Houghton-Mifflin, 1980.

Peterson, R. T. *A Field Guide to the Birds of Texas and Adjacent States.* Boston: Houghton-Mifflin, 1979.

Study the drawings and descriptions in this guide so that you can recognize the common seashore birds of the Gulf Coast when you see them. Use the identification sheets to keep a record of the birds you identify. Add more sheets as you identify birds that are not shown in this guide.

	SEASHORE BIRD AND DESCRIPTION	OBSERVATIONS			
		Date Seen	Place Seen	HABITAT (marsh, beach, etc.)	Identifying Characteristics
	LOONS. Loons are swimming birds that are well adapted for catching fish. The sharp, pointed bill is a characteristic feature. Loons, like grebes, are expert divers.				
	GREBES. Grebes are duck-like, swimming waterbirds and are expert divers. They are distinguished from ducks by their pointed bill, narrow head and neck, and tailless appearance. Grebes normally hold their necks erect, whereas loons and ducks usually hold their necks erect only when alarmed.				
	PELICANS. Pelicans are extremely large birds with long, flat bills and large throat pouches. They are powerful fliers, often gliding only inches above the water. They dive into the water from heights of 30 feet to catch small fish.				
	CORMORANTS. Cormorants are large, black waterbirds with thick necks and long bills. They are fish eaters that dive from the surface and swim underwater.				
	HERONS and BITTERNS. Herons and bitterns are wading birds that have long legs, necks, and bills. They fly slowly with their heads drawn back.				
	SCOTERS. Scoters are medium-size, black-colored sea ducks. They are usually seen during the winter in flocks, sometimes flying low over the waves.				
	RAILS. Rails are medium-size birds that have short necks, long legs, and long toes. They are secretive, marsh birds that are more often heard than seen.				

	SEASHORE BIRD AND DESCRIPTION	OBSERVATIONS			
		Date Seen	Place Seen	HABITAT (marsh, beach, etc.)	Identifying Characteristics
	COOTS. Coots are duck-size birds and have white bills and dark bodies. They are often seen in **estuaries**, diving for food. When swimming, coots pump their necks back and forth.				
	PLOVERS. Plovers are medium-size seashore birds with long, pointed wings and short bills that look swollen near the tip. They are active feeders, and are often seen walking or running swiftly along the shore. Killdeer are members of the plover family and are easily identified by their two black breast bands and noisy cry.				
	TURNSTONES. Turnstones are plump, black-and-white birds of medium size. They are often seen on rocks against which the surf is breaking.				
	CURLEWS. Curlews are large, brown seashore birds with very long, down-curved bills. They are found in marshes, mud flats, and on beaches.				
	SANDPIPERS. Sandpipers are small-to-medium-size seashore birds with slender bills. They are common on beaches or muddy shores where they run along the edge of the water, probing in the mud or sand for food.				
	AVOCETS. Avocets are identified by their long, thin, upturned bills and by their unusually long, thin, blue legs. Avocets have light-brown heads and necks and black-and-white markings on their wings. They are commonly seen in **lagoons** and fish around mud flats.				

SEASHORE BIRD AND DESCRIPTION		OBSERVATIONS			
		Date Seen	Place Seen	HABITAT (marsh, beach, etc.)	Identifying Characteristics
	STILTS. Stilts, like the avocets, have long, thin legs and necks. However, unlike avocets, their long, thin bill is straight and their legs are red. Stilts have black feathers above and white ones below. They are commonly found in marshes.				
	PHALAROPES. Phalaropes are small, sandpiper-like birds that are equally at home swimming or wading. They have long necks and legs. They are found in tide pools and kelp beds beyond the surf. In shallow water, pharlaropes spin in circles to stir up food.				
	GULLS. Gulls are common along all seashores. They are strong birds with webbed feet, long pointed wings, a hooked bill, and usually a square tail. Gulls are SCAVENGERS, often gathering in large groups around docks.				
	TERNS. Terns are slender birds and have long narrow wings, forked tails, and a pointed bill. They dive from the air for small fish or insects. Terns prefer marshy areas.				
	OYSTER-CATCHERS. Oyster-catchers are large, black birds with bright red bills. They are waders, preferring rocky shores where they are occasionally seen prying shellfish off the rocks.				

VOCABULARY

Estuary—an inlet of the ocean, usually formed at the mouth of a river. Estuaries are important feeding areas for birds.
Habitat—the region or type of environment where an organism, such as a bird, is found.
Lagoon—a shallow, pond-like body of water that usually has an opening to the ocean.
Marsh—low soft, wet land tha* is often an important nursery and feeding area for birds.
Scavenger—an animal that eats decaying matter or refuse.

Activity: **Waterfowl**

The following birds are found around the seashore or marshes. As you find the name of each bird, check it off on the list below.

T	A	I	L	S	U	B	R	D	E	N	R	E	T	T	I	B
I	E	F	K	N	M	U	M	E	A	A	G	U	L	L	S	U
N	W	L	F	O	R	M	N	U	P	B	G	S	S	B	O	F
G	G	H	O	W	O	O	L	U	K	I	E	D	K	A	R	L
B	R	I	I	Y	R	S	C	L	U	O	P	A	E	T	O	E
I	L	W	Y	E	F	G	O	S	S	R	O	D	P	O	U	G
L	I	A	H	G	S	S	O	O	E	K	S	K	N	O	C	N
L	A	M	M	R	M	X	T	K	L	A	P	O	C	A	O	T
T	R	S	P	E	L	I	C	A	N	E	R	F	U	S	S	E
B	N	C	R	T	I	F	E	G	C	G	E	F	D	O	E	B
R	R	N	K	S	W	B	U	M	A	O	Y	B	B	U	V	D
J	E	U	V	S	R	E	V	O	L	P	Y	K	E	M	O	R
L	T	E	I	R	T	R	V	E	O	T	A	N	O	R	M	D
K	U	M	G	K	X	U	E	E	T	A	U	Y	W	U	G	L

bittern
coot
grebe
gulls
herons
loon
osprey
pelican
plovers
rails
sandpiper
snowy egret
tern

CONCEPT O

The marine turtles are reptiles which differ from one another in the maximum weight attained, feeding habits, and geographical distribution.

Objectives

Upon completion of this concept, the student should be able:

a. To give the common name of the five marine turtles found in the Gulf of Mexico.
b. To discuss the similarities and differences in diets of the marine turtles.
c. To prepare a written report about one of the five marine turtles studied. (This requires library research.)

THE SEA TURTLES (PHYLUM CHORDATA)
(Subphylum Vertebrata, Class Reptilia)

The marine turtles found in the Gulf of Mexico include the leatherback (the world's largest living reptile) and four species of hardshelled sea turtles. The latter are represented by the very large and common loggerhead, the much smaller, less common Atlantic ridley, the rare Atlantic green turtle, and the Atlantic hawksbill. All of these marine turtles may be recognized by their flipper-like legs. These animals spend virtually their entire lives in the water, emerging on beaches only to lay eggs. All five marine turtles can be destroyed quite easily. With the exception of the leatherback, all species are considered edible.

Marine turtles are most easily wounded by man when they emerge from the sea to bury their eggs in nests on sandy beaches. At such times the adults may be slaughtered for food. Thousands of eggs are collected to be prepared and eaten in much the same manner as hen's eggs. In addition to harvesting by man, the eggs are eaten by many other animals including pigs, dogs, raccoons, and skunks. If a nest remains undisturbed and the eggs hatch after a month or more, the young turtles usually emerge at night and head for the sea.

Atlantic Leatherback Turtle

The leatherback, *Dermochelys c. coriacea,* may be distinguished from all other marine turtles because it has no **plates** on its shell and no scales on its head or body. Instead, the leatherback is covered by a skin that appears leathery or rubbery. The top shell has seven ridges which run lengthwise (Figure 1A).

The leatherback spends most of its life in the open ocean. This species is the only turtle known to be warm-blooded and capable of maintaining body temperatures near 80°F. The turtle maintains this temperature even when living at sea temperatures near 45°F.

Because leatherbacks can maintain their body temperature, they can survive in cool northern waters as well as the Gulf of Mexico and Caribbean Sea.

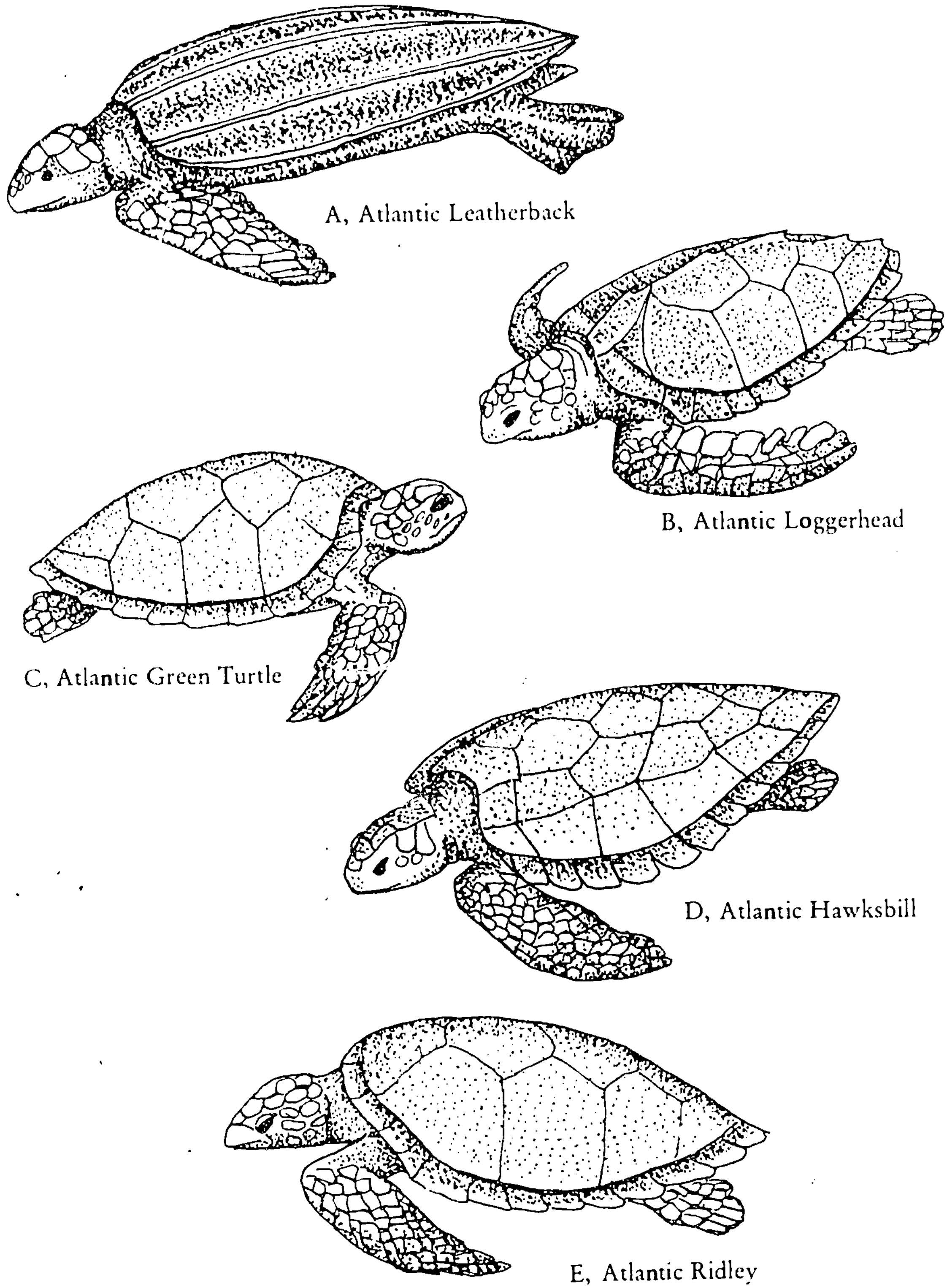


Figure 1. Sea Turtles.

Atlantic Loggerhead Turtle

The loggerhead, *Caretta c. caretta*, is the largest of the hardshelled sea turtles (Figure 1B). It has a weight of at least 1000 pounds and perhaps 1200 pounds. This turtle occurs frequently in **subtropical** areas. It has been seen several hundred miles at sea, yet also is found in **estuaries** far up into **brackish** water. The loggerhead's diet is quite varied. It includes jellyfishes, sponges, mollusks, crabs, shrimp, barnacles, fish, and various sea grasses.

Atlantic Green Turtle

The green turtle, *Cheloni m. mydas*, attains a weight of 850 pounds (Figure 1C). It is a **tropical** species which undertakes long oceanic migrations. The green turtle also feeds in shallow areas, particularly near sea grass beds. Normally coming ashore only to nest, these turtles have occasionally been observed "sunning" themselves in the tropics. Since young green turtles eat jellyfishes, mollusks, and crustaceans, they are more **carnivorous** than the adults. The adults feed heavily on a sea grass called *Thalassia* and other marine plants.

Atlantic Hawksbill

The hawksbill, *Eretmochelys i. imbricata*, attains a weight of 280 pounds, but most individuals are much smaller (Figure 1D). The hawksbill tends to be restricted to the tropics more so than any of the other marine turtles. It has been found most often in shallow areas near rocky or coral **reefs** and in estuaries and **lagoons**. The hawksbill has been reported to be **omnivorous**, but tends to include more animal than plant material in its diet. A wide variety of animal food has been recorded, including sponges, coral, Portuguese man-of-war, sea urchins, mollusks, fish, and crustaceans.

Atlantic Ridley

The ridley, *Lepidochelys kempi*, has a maximum weight of 110 pounds (Figure 1E). It is a coastal sea turtle, being most often encountered in **mangrove habitats**. The ridley's diet consists mostly of **benthic** animal matter, including mollusks and crustaceans.

VOCABULARY

Benthic—living in or on the ocean floor.

Brackish—less salty than the ocean; estuaries are brackish because fresh river water mixes with salty ocean water.

Carnivore—an animal which preys on other animals.

Estuary—a relatively small body of water that is set off from the main body of water and is affected by the rise and fall of the tide. Estuaries contain mixtures of fresh and salt water.

Habitat—the place where an organism lives.

Lagoon—a shallow sound, channel, or pond near or associated with a larger body of water.

Mangrove—a tropical tree or shrub that develops many roots. Mangrove swamps are active land builders.

Omnivore—a consumer which feeds upon both plants and animals.

Plate—a section of hard material which makes up a turtle shell.

Reef—a ridge of rocks or sand at or near the surface of the water.

Subtropical—geographical regions that border on the tropical zone.

Tropical—areas between latitudes 23° 30′ north and south of the equator which have warm temperatures with little season differences.

CONCEPT P

Besides being intelligent and economically important, the marine mammals have made numerous biological adaptations in order to survive in their environment.

Objectives

Upon completion of this concept, the student should be able:

a. To discuss some of the adaptations that marine mammals have made in order to stay warm.
b. To list seven groups of organisms that are marine mammal[illegible]
c. To prepare a written report about the economic impor[illegible] [illegible] ...ires librar[illegible] [illegible]rch.)
d. To di[illegible]entiate between the terms "dolphin" and "porpoi[illegible]".
e. To compare and contrast the structures used for swimming by seals and sea otters.

MARINE MAMMALS (PHYLUM CHORDATA)
(Subphylum Vertebrata, Class Mammalia)

Marine mammals include whales, dolphins, porpoises, seals, sea lions, walruses, and sea otters. Like land mammals, they are warm-blooded and nourish their young on the mother's milk.

The bodies of marine mammals are well adapted for life in the sea. Most are streamlined, making it easier for them to move through the water. Seals' limbs are modified to form flippers, while sea otters have flipper-like hind feet. Instead of vertical tails like fish, whales have horizontal tails—an adaptation that enables them to dive and surface easily. Whales combat cold ocean waters by insulating their bodies with a thick layer of fat (blubber). The blubber also provides buoyancy, padding, and a source of energy when food is scarce. Sea otters depend on long, fine, thick coats of hair for warmth. Seals have both a layer of fat and a coat of hair to keep them warm.

Young marine mammals are born well developed and with their eyes open. The high protein and fat content of the milk of marine mammals puts fat on the young quickly, giving them needed insulation from the cold and providing energy for metabolism. The young grow fast and can take care of themselves early in life. These adaptations are essential to survival in the hazardous marine environment.

Perhaps the most fascinating aspect of marine mammals, especially whales, is their ability to dive deep into the ocean and stay down a long time. Although their lungs are not much larger in size than those of land mammals, sperm whales can dive to depths of 3,000 feet and stay down for as long as 90 minutes.

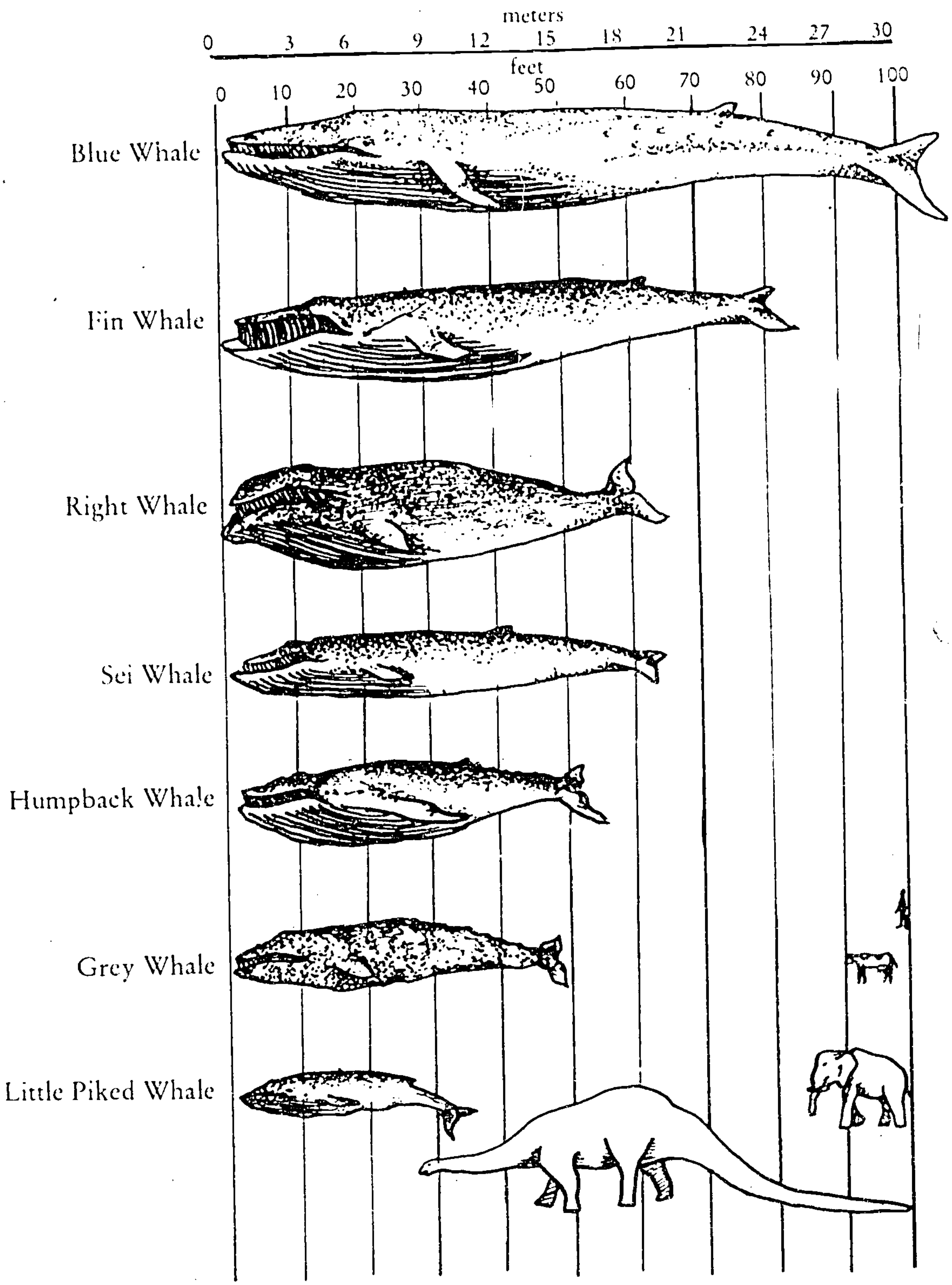


Figure 1. Size Comparisons of Whales.

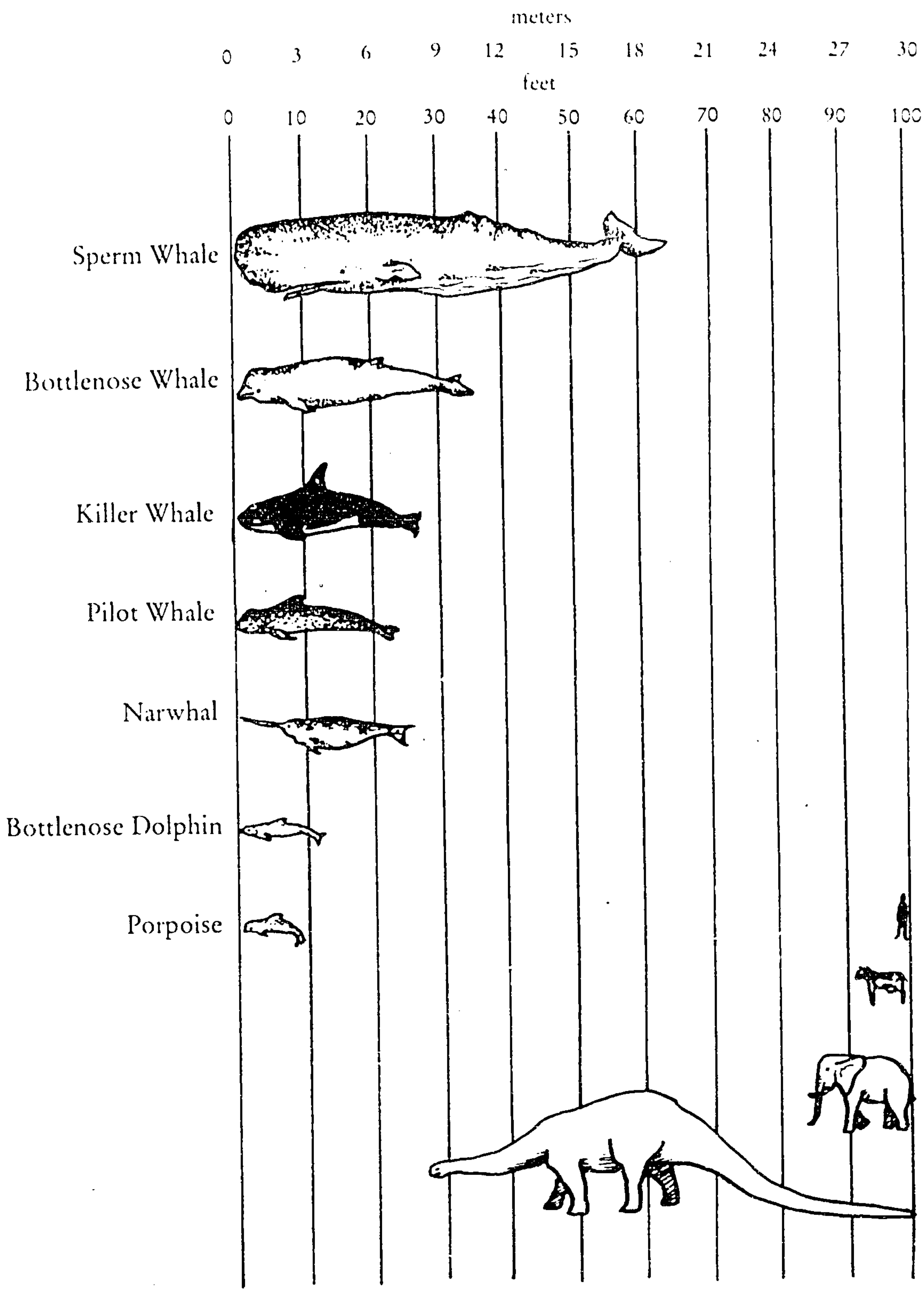


Figure 2. Size Comparisons of Whales, Dolphins, and Porpoises.

Whales and dolphins, also called **cetaceans**, have always caught the fancy of man because of their size, beauty, and playfulness. They have been valuable to man for centuries as a source of food and oil.

The scientific name of the order, Cetacea, comes from "cetus", the early Greek and Latin word for whale. The cetaceans are divided into two groups, toothed whales and baleen whales. **Baleen** whales have no teeth; instead, sheets of a fringed, horny material, called whalebone or baleen, hang from their upper jaws. Baleen whales feed on **plankton**, strained through the baleen, and also on small fishes and shrimp.

Whales are the largest animals known. In fact, the blue whale, which reaches a length of 100 feet and a weight of more than 100 tons, is the largest animal that has ever lived (Figure 1). Whales can grow so large because of the abundance of plankton on which they feed. Not all whales are large, however. Some, like the pygmy sperm whale, reach a length of only 13 feet.

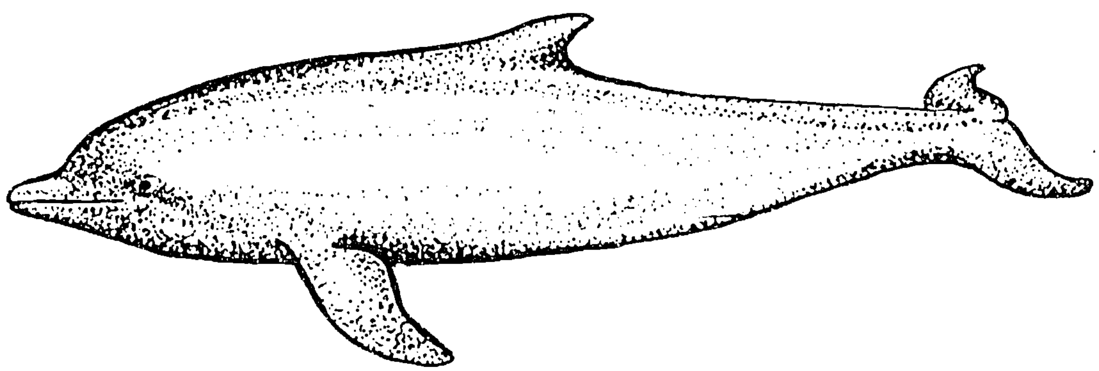


Figure 3. Bottlenose Dolphin.

"Dolphin" and "porpoise" are terms that often cause confusion. Strictly speaking, the long-beaked forms are called dolphins and the small, snubby-nosed forms are called porpoises (Figure 3). However, these words are commonly used interchangeably.

Cetaceans have poor senses of smell and taste, but good eyesight and excellent hearing. Whales and dolphins are apparently very intelligent mammals. They make a variety of sounds, both for "talking" with one another and for use as a sort of **sonar**. This sonar is used to locate food and avoid underwater objects. Cetaceans breathe through nostrils (blowholes) on top of the head.

Cetaceans usually give birth to only one offspring each year. The young are large at birth, usually one-fourth to one-third or more the length of the mother. For example, an 80-foot blue whale may give birth to a baby that is 25 feet long and weighs 2 tons or more. The young grow rapidly, doubling their length within the first year.

Whaling, the commercial fishing of whales for food and by-products, has been carried on for many centuries. In the early 1800's, the main products taken from whales were oil, spermaceti, and whalebone, used in making women's garments. Indians once made necklaces of the ear bones of whales, which they believed brought good luck. Today whale oil is used in the manufacture of soap, cosmetics, shortening, lubricants, and many other products. The rest of the body is used for human or animal food and for fertilizer. Ambergris is the most valuable product from whales. It is used in the finest perfumes.

Man's toll on whales has been so heavy that some species, including the blue whale, are now regarded as endangered. Whaling ended in the United States in 1971 when a law was passed protecting eight species of whales. Although international regulations have been set, enforcement has not been effective.

Seals and Sea Lions

Pinnipeds—the seals, sea lions, and walruses—are well adapted for life in the sea. The name pinniped, which means featherfeet, refers to the modification of the front and hind feet to form flippers. These flippers allow many of the pinnipeds to be excellent swimmers. Some pinnipeds, such as the harbor seal, may spend six to eight months at sea, without touching land during that time (Figure 4A). Others, such as the northern fur seal, spend considerable time on land. Pinnipeds have thick hides with heavy layers of fat underneath and, in some cases, fur to protect them from the cold.

The seals and sea lions can be separated into two groups, the eared seals and the hair seals. Eared seals have small, external ear flaps. They can turn the hind flipper forward, enabling them to move rapidly on land. They use large front flippers for swimming (Figure 4A). Eared seals breed in special areas called rookeries, commonly on offshore islands, to which they may return year after year. Hair seals have no external ears. Unlike eared seals, they cannot turn their hind flippers forward. Consequently, they are clumsy on land. Hair seals have smaller front flippers than do eared seals. Hair seals primarily use their hind, rather than front, flippers for swimming (Figure 4B).

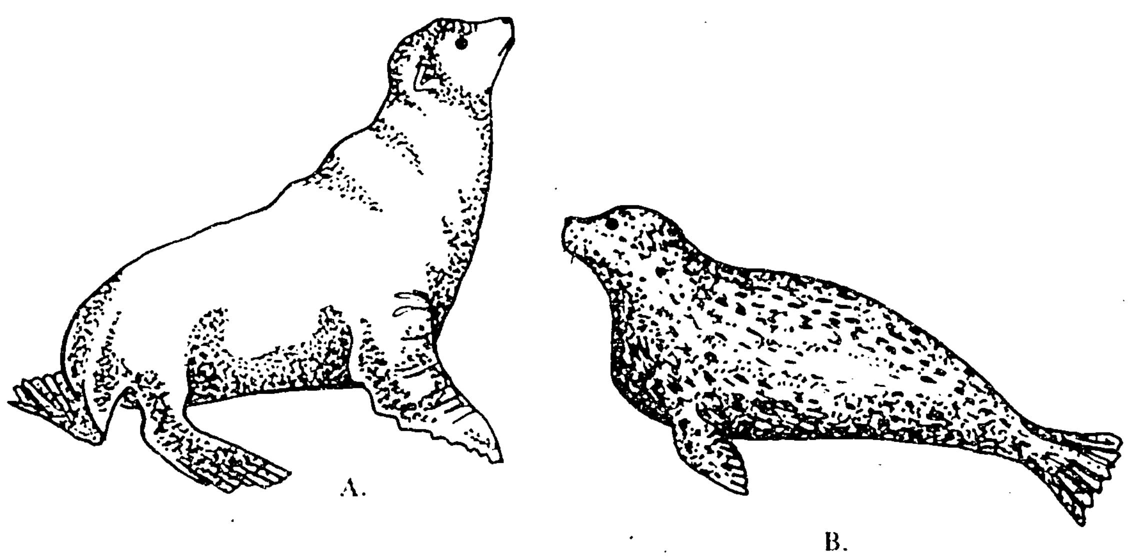


Figure 4. Seals. A, Eared seal. B, Hair seal.

Sea Otters

The sea otter is a member of the weasel family (Figure 5). Sea otters are closely related to river otters, but are considerably larger. They often reach lengths of 4½ feet and weights of 70 to 80 pounds. Their front paws, used for holding food and other objects, are stubby and rounded. The hind feet are large and webbed. Along with the tail, the hind feet are slightly flattened for use in swimming. When moving rapidly, sea otters swim on their backs. They can dive to 300 feet and remain underwater four to five minutes to hunt for food.

Sea otters eat sea urchins, mussels, crabs, snails, and a variety of other foods. They rarely eat fish. Since sea otters lack a layer of blubber, they depend on their fur and on food to maintain body heat. Indeed, an adult male easily can eat 15 pounds of food a day, nearly one-fourth of its body weight.

Sea otters breed and give birth throughout the year. Birth apparently takes place in the water. Since pregnancy lasts eight or nine months and a female has only one pup every two years, population increase is slow.

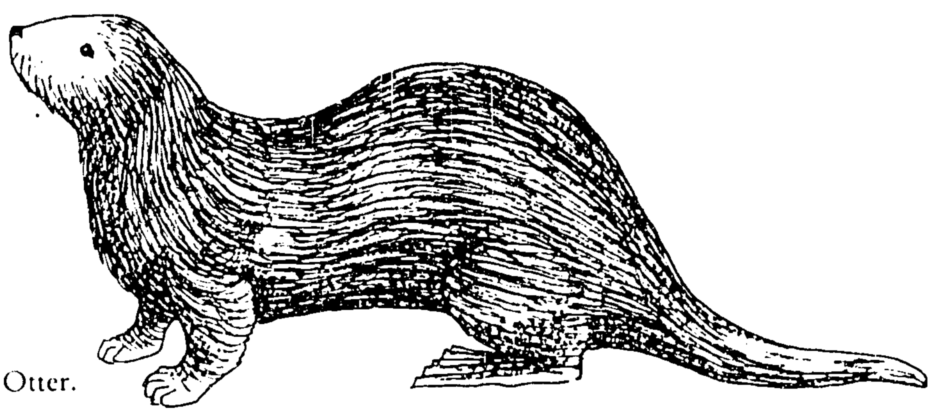


Figure 5. Sea Otter.

VOCABULARY

Adaptation—the process by which a species becomes suited to survive in an environment.

Ambergris—a waxy substance from the sperm whale used in making perfumes.

Baleen—the horny material growing down from the upper jaw of large plankton-feeding whales which forms a strainer or filtering organ.

Blubber—the fat of large sea mammals.

Cetaceans—whales and dolphins.

Environment—the surroundings of an organism.

Mammal—a group of vertebrate animals which nourish their young with milk.

Pinniped—a group of animals whose front and hind feet are modified to form flippers.

Plankton—small plants and animals floating in the upper layers of the water column.

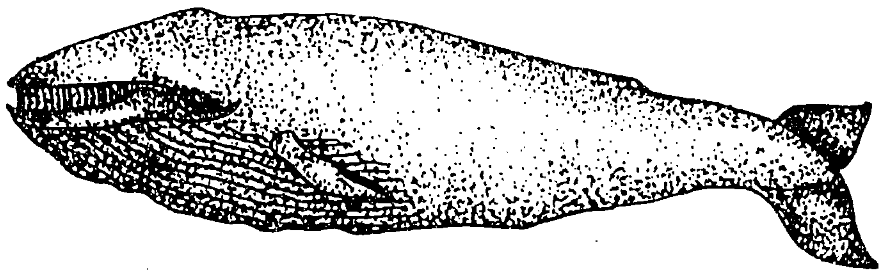
Sonar—a system that detects the presence and location of submerged objects by reflected vibrations.

Spermaceti—a substance, obtained from whales, that is used in lamps and for making candles.

Whaling—the commercial fishing of whales for food and by-products.

Activity: The World of Whales

Unlike the huge prehistoric dinosaurs, which had very small brains, the huge whale has a very large brain and displays considerable intelligence. Whales are now an "endangered species" as modern harpoons and lack of regulations are causing them to be killed off very rapidly.



baleen
belugas
blowhole
blubber
blue whale
bowhead
bull
cachalot
calf
cetaceans
cow
dive
dorsal fin
flipper
flukes
harbor dolphin
hair
herd
humpback
hunt
mammal
milk
ocean
oil
plankton
rorquals
sea
sounds
sperm
spout
submerge
surface
swim
tail
warm-blooded
waves
whalebone

D	L	K	H	U	M	P	B	A	C	K	J	H	G	E
M	I	L	K	J	H	S	N	A	E	C	A	T	E	C
M	A	V	R	O	R	Q	U	A	L	S	D	F	B	A
I	T	M	E	R	T	B	O	W	H	E	A	D	L	F
W	A	R	M	B	L	O	O	D	E	D	E	L	U	R
S	S	H	I	A	S	B	I	J	N	D	U	N	E	U
O	A	E	J	A	L	E	N	L	O	B	N	P	W	S
U	G	R	T	U	H	O	K	R	B	J	P	S	H	U
N	U	D	B	U	T	Y	S	U	E	I	U	E	A	B
D	L	B	N	K	O	A	S	F	L	A	C	V	L	M
S	E	T	N	C	L	P	O	F	A	F	J	A	E	E
R	B	A	E	F	E	H	S	W	H	G	F	W	E	R
O	L	A	I	R	E	L	O	H	W	O	L	B	S	G
P	N	N	M	C	A	C	H	A	L	O	T	Y	E	E
L	K	N	I	H	P	L	O	D	R	O	B	R	A	H

REFERENCES

Diversity of Marine Animals

CONCEPT A

Crews, *et al. Animals of the sea: protozoa.* n.d.
(Marine Education Materials System, No. 000004).

CONCEPT B

Awkerman, Gary L. *Animals of the sea: sponges.* n.d.
(Marine Education Materials System, No. 000006).

Activity: Sponge Structure

Bedard, A. *et. al. Marine and environmental studies field manual.* 1973.
(Marine Education Materials System, No. 000603).

Activity: Aggregation of Sponge Cells

Bedard, A. *et al. Marine and environmental studies field manual.* 1973.
(Marine Education Materials System, No. 000603).

CONCEPT C

Crews, A. *et al. Animals of the sea: coelenterates.* n.d.
(Marine Education Materials System, No. 000002).

Activity: General Behavior and Feeding Behavior of *Hydra*

Bedard, A. *et al. Marine and environmental studies field manual.* 1973.
(Marine Education Materials System, No. 000603).

CONCEPT D

Crews, A. *et al. Animals of the sea: ctenophores.* n.d.
(Marine Education Materials System, No. 000003).

CONCEPT E

Polychaetes of Mississippi Sound. 1978. Marine Educational Leaflet
No. 10. Biloxi: Marine Education Center.

Zinn, Donald J. *A handbook for beach strollers.* 1973.
(Marine Education Materials System, No. 000052).

Activity: How Does *Nereis* React to a Changing Environment?

Bedard, A. *et al. Marine and environmental studies field manual.* 1973.
(Marine Education Materials System, No. 000603).

Activity: Oxygen Consumption by Marine Worms

Bedard, A. et al. *Marine and environmental studies field manual.* 1973.
(Marine Education Materials System, No. 000603).

CONCEPT F

Zinn, Donald J. *A handbook for beach strollers.* 1973.
(Marine Education Materials System, No. 000052).

CONCEPT G

Schena, R. *Echinoderms.* 1979.
(Marine Education Materials System, No. 000820).

CONCEPT H

Zinn, Donald J. *A handbook for beach strollers.* 1973.
(Marine Education Materials System, No. 000052).

Activity: Anatomy and Feeding Behavior of Barnacles

Bedard, A. *et al. Marine and environmental studies field manual.* 1973.
(Marine Education Materials System, No. 000603).

CONCEPT I

Blue Crab. 1975. Marine Educational Leaflet No. 5. Biloxi:
Marine Education Center. (Marine Education Materials System, No. 000368)

Cucchesi, L. *The blue crab: Callinectes Sapidus*
(Marine Education Materials System, No. 000024).

Zinn, Donald J. *A handbook for beach strollers.* 1973.
(Marine Education Materials System, No. 000052).

Activity: Hermit Crab Behavior

Demanche, Sister E. L. *Reef and shore.* 1976.
(Marine Education Materials System, No. 000186).

CONCEPT J

The biology (life cycle) of Penaeid shrimp in Mississippi waters. 1976.
(Marine Education Materials System, No. 000337).

CONCEPT K

Corcoran, Gerald C. *The horseshoe crab.* Biloxi: Marine Education Center: (Marine Education Materials System, No. 000336).

The horseshoe crab: Limulus polyphemus. University of Rhode Island Marine Advisory Service.

CONCEPT L

Cockrum, E. Lendell and William J. McCayley. *Zoology*. Philadelphia: W. B. Saunders Company, 1965.

D'Ombrain, Sheila A. *The beachcomber's study guide*. 1966. (Marine Education Materials System, No. 000303).

Elliott, Alfred M. *Zoology*. New York: Appleton-Century-Crofts. 1963.

CONCEPT M

Corcoran, Gerald C. *Sharks*. n.d. (Marine Education Materials System, No. 000224).

Stingrays. n.d. (Marine Education Materials System, No. 000224).

CONCEPT N

Dewees, C. and J. Hooper. *Identifying seashore birds*. 1977. (Marine Education Materials System, No. 000057).

CONCEPT O

Musick, J. A. *The marine turtles of Virginia*. 1979. (Marine Education Materials System, No. 000819).

CONCEPT P

Dewees, C. and Hooper, J. *Marine mammals*. 1975. (Marine Education Materials System, No. 000118).

Activity: World of Whales

The American Cetacean Society, NMEA Conference, 1979.

Index

Index to Scientific Names